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THE PROGRESS OF SCIENCE

THE DEARTH OF SCIENCE TEACHERS

Some months ago Sir Richard Southwell gave a very stimulating lecture to the Royal Society of Arts on the subject of the "Training of Science and Technology". No one in Britain is better qualified to discuss this subject than Sir Richard, who was professor of engineering at Oxford for many years before he became rector of the Imperial College of Science and Technology in London, and we recommend this lecture to the attention of our readers.* But quite apart from the wise remarks it contains on the main theme the lecture is noteworthy because of the great emphasis which Sir Richard gave to the fact that all scientific and technological training must wither at the roots if the shortage of science teachers in British schools is allowed to continue. The larger output of scientists and technologists calls for a steady output of science students from the schools, and yet the schools have been stripped of the men on whom it depends—the science masters. Sir Richard predicted that with science teachers so scarce the universities may quite soon have to lower their standards of admission. Our information is that this has already happened in more than one university science department.

Sir Richard used the following words when speaking about science teachers: "No one seems to have thought about 'growing for succession'! We have been eating our seed-corn, and if famine results we cannot disclaim responsibility." His vivid metaphors certainly helped to bring home effectively the seriousness of the shortage of science masters without exaggerating it in any way. Britain has indeed been eating its seed-corn with little thought of the future, for this shortage has developed during the period between 1939 and today, a period in which the annual 'harvest' of new science graduates leaving the universities has practically doubled in quantity.

* The lecture—the R.S.A.'s Trueman Wood Lecture—is due for publication in the *Journal of the Royal Society of Arts* this month (October).

In Scotland the need to find remedies for this situation has been fully recognised. The Secretary of State for Scotland has not waited to be pushed on this issue, and has appointed a committee headed by Sir Edward Appleton to inquire into the supply of science and mathematics teachers —and, even more important, *to suggest remedies*. It is to be hoped that the Government will lose no time in taking steps to deal with the problem as it affects England and Wales, where the shortage of science teachers is even more acute than it is in Scotland.

A good many facts about the shortage have already been collected, and there is reasonable agreement about the major factors which have caused it. For example, there was the survey made in 1952 by the "Joint Four"—the four associations representative of headmasters and assistant masters in public and grammar schools. Its results were the subject of the now classic leader in *Nature* (December 27, 1952), which concluded that some 250 science posts would remain unfilled during the whole of the 1952-3 school year. That leader also stressed the fact that the quality as well as the quantity of new entrants to the profession was low. (Only 39% of the teachers starting in September 1952 had honours degrees, as compared with 55% before the war.)

We agree with *Nature*'s contention that one of the main reasons behind the shortage is that science masters' salaries compare unfavourably with the starting salaries offered to scientists by industry and Government departments.

Two section presidents of the British Association, Mr. Robert Birley and Prof. G. R. Clemo, took up this point at last month's meeting in Liverpool. Mr. Birley, who is headmaster of Eton, said that it would be blindly foolish of the nation not to ensure that the salaries of masters in grammar schools are raised to a figure high enough to attract able scientists into the teaching profession. Prof. Clemo, director of the Chemistry Department at King's College, Durham University, gave figures showing how a

science master's financial prospects compared with those of an industrial chemist. These figures he summarised in the following table:

Age	Teaching (Grammar Schools)	Industry (from Institute of Chemistry statistics)
	Average Salary	
32	£651	£1,004
35	£705	£1,244
46	£726	£1,651
	Special responsibility £50–£100	Many industrial salaries are increased by 20%

He said, moreover, that pensions also favour considerably the industrial chemist. He also mentioned the fact that science masters have less chance of becoming headmasters than classics masters, for example.

We agree with Prof. Clemo that it is not easy to suggest a full solution to this serious problem, but certainly a solution has to be found and right quickly. The salary question is undoubtedly very important, and a way must be found to make science teaching financially more attractive. On this point it is worth quoting again the remarks of Dr. Eric James, an ex-science master who is now High Master of Manchester Grammar School, which appeared last year in DISCOVERY (August 1952, p. 254):

We are working with a salary structure that postulates that all teachers are virtually worth the same, and pays a teacher who at some stage scraped through school certificate and underwent a two-year course in a training college the same basic salary as the man who secured a first in physics. The indiscriminate demand to raise teachers' salaries is no answer at all: the only real solution is to establish adequate differentials by which sixth-form work, which after all makes greater intellectual demands than much of what is done in technical colleges and all of the work of training colleges, receives adequate rewards. It will probably take a Royal Commission to bring this about, but sooner or later the hard facts of economic survival will make it necessary.

Equally relevant at the present time was another suggestion made by Dr. James in the same article:

The universities can help by pressing upon students the claims and attractions of grammar school teaching. *It may be that the situation is so urgent that teaching should be regarded as an alternative form of national service.*

Whatever body does eventually accept the vitally important task of collecting all the essential facts and thrashing out a practical plan to end the shortage, it is bound to find many valuable pointers in the new report entitled "Results of Inquiry into Conditions affecting the Teaching of Science in Grammar Schools", which was prepared jointly by the Science Masters Association and Association of Women Science Teachers. This document contains many relevant statistics, and also some very revealing comments, on the state of science teaching in individual schools, sent in by headmasters and senior science masters. Here is one comment from this document which we thought particularly worth bringing to the notice of readers:

A large number of Science graduates who intended to take up teaching were directed to war work. Most of these remained in industry because a return to teaching would have

meant a year's training without salary and a lower salary than industry offered. In my own case the drop in salary was over £200 per annum.

Teaching posts in the Services carry a higher salary. For example £1500 per year for married officers reaching to £1800 by selection. Teaching posts in Junior Technical Schools carry about £60 per annum more, although the work is less advanced than Leaving Certificate presentation. The Honours Graduate in Science who decides to teach in a higher Technical College is not required to train for a year in a teachers' training college, yet he is given a higher salary, and conditions which require him to attend on the students only fifteen hours per week, with the rest of his time available for research. These more attractive conditions reduce the appeal of the Grammar Schools.

I have interviewed a number of University Students with a view to persuading them to take up Science teaching. In every case I was unsuccessful. Those students in their final honours year had already been provisionally engaged for an industrial post under more attractive conditions, e.g. salary, non-contributory superannuation, expenses, use of the firm's car outside working hours.

A number of good Science pupils prefer to study Medicine at the University, because this means starting to earn a salary sooner. For example the Science graduate spends four years at the University, one year in training and two years military service, i.e. a total of seven years before starting on his salary scale. The Medical student starts earning a salary after six years at the University, first as a trainee in a hospital and then at full medical officers' rates in the services.

Reading through this document one is impressed by the great difficulties which senior science masters encounter when they have to fill vacancies. Advertisements of vacant posts bring very few applications; two or three seem to be an average response, and even then only one applicant usually has suitable qualifications. As one comment expressed it: "Almost always 'Hobson's choice' when a vacancy occurs."

How acute the shortage of science masters is can be appreciated from this example. A school advertised for a physics master; only four replies were received, all from graduates with pass degrees. At the same time the school advertised for a French master; the result was 82 replies, seven from men with first-class degrees. Pre-war, all the science staff at this school had honours degrees; the last three science masters to join had pass degrees only.

The practice of 'seed-corn eating' obviously stands condemned already. The problem now is: how can matters be put right again with all possible speed and with least possible friction.

TWO NEW ANTIBIOTICS

Among the vast amount of medical research which is going on at the present time, one particular field which has yielded big dividends during the past few years is that of the antibiotics.

The principal method of obtaining moulds for examination for potential antibiotics is to grow them from soil samples taken from all over the world. The magnitude of this task is obviously immense and, by now, hundreds of thousands of soil samples have been subjected to scrutiny by the firms, sixteen in the United States, engaged in this research. Many moulds are cultivated and many antibiotics

are isolated, but very few indeed ever prove to be of any value. The chances of finding a winner are slim, and the search for new antibiotics has something in common with the exercise of looking for the proverbial needle in a haystack! Thus, before terramycin was discovered in 1950, 100,000 samples of soil were investigated. Now, after a comparative lull, two further useful antibiotics have been discovered during the past year or so as a result of this painstaking work. They are *erythromycin* and *carbomycin*.

Erythromycin derives its name from the mould which produces it, *Streptomyces erythreus*, grown in the research laboratories of Eli Lilley in the United States from a sample of soil taken from Panay in the Philippines.

Carbomycin is another American discovery. Like terramycin, it was isolated in the Pfizer research laboratories. This antibiotic shows considerable promise. Derived from the mould *Streptomyces halstedii*, it is perhaps better known under the proprietary name of 'Magnamycin'.

Both erythromycin and carbomycin can be given by mouth, and they both appear to have a wide range of usefulness combined with a very low toxicity. They have been found effective against many bacteria and some of the larger viruses such as those which cause psittacosis and Rocky Mountain spotted fever.

Whilst they show no striking advances over the other so-called 'broad spectrum' antibiotics, which include chloromycetin, aureomycin and terramycin, they are sufficiently good to warrant their large-scale production. One of their most important uses will be in those circumstances where bacteria have become resistant to the older antibiotics. Moreover, where an allergy to an antibiotic develops it is always useful to be able to substitute the antibiotic causing the trouble with another not liable to do so.

Unfortunately, in common with all the antibiotics, resistant strains of bacteria develop to both erythromycin and carbomycin; in the case of the former this happens rather quickly. Carbomycin would appear to be less potent than erythromycin, as comparisons show that a greater concentration is required to inhibit bacterial growth.

Tests now being carried out with these two new antibiotic weapons will doubtless reveal their true place in the overall plan of the antibiotic treatment of disease.

Not all research, however, is being directed into the discovery of new antibiotics. Much work has been and is currently being carried on to try to increase the effectiveness of those already established. A fairly recent development in this field is a means of reducing the toxic side effects following the administration of streptomycin, still one of the major weapons in the battle against tuberculosis.

In the case of penicillin the main developments have been connected with the aims of prolonging its action in the patient's body and of improving its keeping qualities.

This is undoubtedly the era of antibiotics. The annual consumption of these drugs in their various forms has already assumed considerable proportions. For example, it was reported a short time ago that the U.S.A. was producing around thirty tons of penicillin each month; for streptomycin, aureomycin, chloramphenicol (chloromy-

cetin) and terramycin the monthly production figure was well over twenty tons in each case.

There is indeed a lot of truth in the old saying in Ecclesiasticus, "the Lord hath made medicines out of the earth and he that is wise will not abhor them".

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AFTER "CAT-CRACKING"—PLATFORMING

The marketing of premium-grade petrols in this country became possible as a result of the construction of the large catalytic cracking units which have been a feature of the new refineries. The principles of the cat-cracker's construction and mode of operation were explained in our columns three years ago (see DISCOVERY, May 1950, pp. 161–4). The general effect of cat-cracking is to raise the octane number of a low-grade petroleum fraction by causing branched-chain hydrocarbons to form from straight-chain hydrocarbons. Even if it were possible in this way to make a product which was 100% of so-called iso-octane, the octane number would only be 100; in practice something nearer 80 is achieved. For piston-engined aircraft this is not high enough, and this country has been dependent for aviation fuel on the United States since the loss of facilities at Abadan.

A step towards independence has been taken by the decision of the Shell organisation to erect a 'platformer' at Stanlow at a cost of £3,500,000. Britain should become self-sufficient when a still larger unit planned by Anglo-Iranian is erected on the Isle of Grain. The term *platformer* is one of the omnibus American words which conveniently expresses a complex title; a 'platformer' is a 're-former' employing platinum catalyst and operates differently from the normal cat-cracker. The 're-forming' operation is carried out on a petroleum naphtha fraction to produce aromatic hydrocarbons, such as benzene, toluene and xylene. Blends of these are capable of yielding a fuel with octane numbers above 100. When the R.A.F. was being built up pre-war, these blends were used as the only source of high-octane fuel. Their origin was the by-products of coal carbonisation which in this country are available in excess of industrial demand for conversion to chemical and other uses.

The impetus to develop production of such high octane fuels from petroleum came in America where the output of coal by-products is relatively small compared with Britain. (This stems from the large-scale replacement of coal-gas by natural gas for domestic and industrial use.) On the other hand, the chemical requirements for aromatics increased enormously because of the growth of demand from the synthetic rubber industry for styrene, from plastics and insecticides for phenol, from detergents for alkyl-aryl-sulphonates and from aviation for cumene. All these were
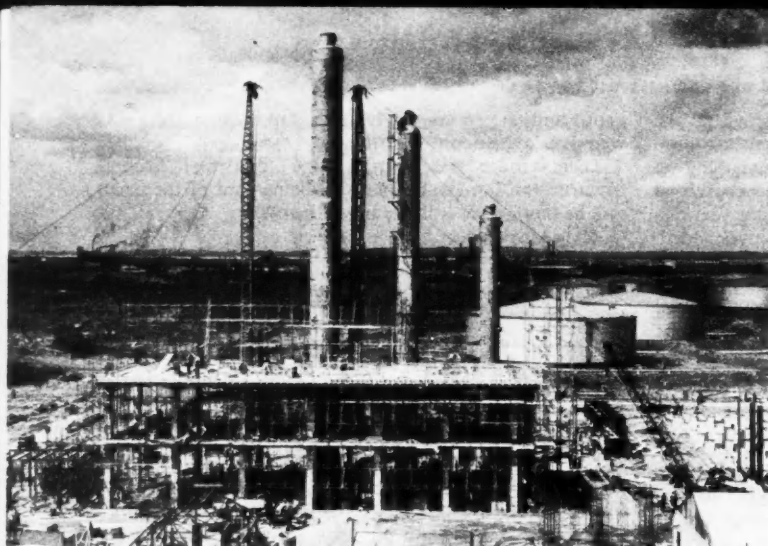
Now under construction at the Stanlow Refinery, near Ellesmere Port, Cheshire, the first 'platforming' unit to be erected in the United Kingdom is scheduled for completion by the end of this year. The 'platformer' is so called because it uses a platinum catalyst to re-form low-grade petrol into high-grade petrol which can be blended into high octane spirit. This new installation was seen by members of the chemical section of this year's British Association meeting.

users of benzene, which also went into the synthesis of nylon. Explosives required toluene in excess of the capacity of the coal by-products industry.

For benzene production, coal-tar products offer an attractive route since they yield benzene, toluene and xylene in the rough proportions of 10:4:1. The straight cracking at high temperatures of petroleum fractions also yields high proportions of benzene.

The 'platforming' process, however, reverses these figures, and xylene forms by far the largest fraction. This arises from the composition of the petroleum naphtha fed to the platinum catalyst and the mode of action of the catalyst. At around 900–1000 F. and a pressure of 200–1000 lb./sq. in., with a large amount of hydrogen in circulation, naphthenic hydrocarbons such as cyclohexane and methylcyclopentane are isomerised and dehydrogenated to benzene. But the amount of material of this kind, single-ring C_6 naphthenes, is limited in petroleum fractions and is outweighed by C_7 and C_8 naphthenes by 4 to 10 times. The product of 're-forming' is therefore correspondingly rich in toluene and xylene.

By the use of the 'platformer' the refiner obtains either very high-grade motor fuel or a source of aromatic chemicals. The xylene content becomes of additional interest since the development of 'Terylene' which is based on terephthalic acid derived from *para*-xylene. (Where the word 'xylene' is used by itself in this note we mean of course the ordinary mixture of the *ortho*-, *meta*- and *para*-isomers.)

A real welcome must be given to these new developments. They round out the refinery facilities available in this country. The advances that have been made and the changing pattern are reflected in a recent set of statistics issued by the Petroleum Information Bureau. The 1952 consumption of petroleum products rose to 17,520,145 tons from 16,887,908 tons in 1951. The use of motor fuel actually declined slightly to 5,440,552 tons from 5,454,266 tons in 1951, suggesting that the high tax is beginning to exert a deterrent effect. This is supported by the increased consumption of diesel fuel, with its greater economy, although the high duty on this fuel also appears to have checked the rate of increase.

The heartening figures are those of production in United Kingdom refineries. In 1951, 2,923,181 tons of motor and aviation spirit were produced at home, but in 1952 the figure rose to 4,935,418 tons. *For the first time Britain produced more refined petroleum products (a total of 22,490,363 tons) than she herself consumed.* The direct economic effects of this surge are welcome enough, but almost as important is the fact that a new generation of technologists are coming along who are being trained at home in the confident atmosphere that goes with an industry which is expanding and developing new production processes.

REFERENCE

The world's first 'platformer' went into production in 1949, in America, and significant references to the process started appearing in technical journals the following year. *Reviews of Petroleum Technology* (Institute of Petroleum), for both 1950 and 1951, should be consulted. *Chemical Engineering* (1952, Vol. 59, No. 5) contains a flow-sheet for the platforming process.

ATTIC PHYSICIST

Science is now so highly professionalised that there remain comparatively few fields in which the amateur working outside a recognised laboratory can make important discoveries. He also faces the difficulty that the results of his work will have to stand the test of very critical scrutiny, more critical probably than that given to the results obtained by a scientist working in a laboratory with an established reputation.

From a field of scientific activity such as nuclear physics which involves the use of elaborate and costly apparatus the amateur is practically disbarred. In spite of this, *Scientific American* is able to record the remarkable case of an untrained solo investigator who has set the nuclear physicists of the U.S.A. by the ears with a discovery of importance in connexion with the development of the synchrotron. This is the story of Nicholas Christofilos and his discovery as told by *Scientific American*.

Three years ago the Radiation Laboratory at the University of California received a long letter from Christofilos, then living in Greece. Mr. Christofilos had an idea which he thought would make it possible to build immensely bigger and more energetic synchrotrons.

The scientists considered the suggestion, were baffled

by the unorthodox mathematics with which Mr. Christofilos ventured to explain it, and decided the idea would never work. Christofilos, undiscouraged, was so sure he was right that he applied for patents on his principle. His idea lay quietly buried in the U.S. Patent Office until a few months ago when a team of physicists at the Brookhaven National Laboratory, who had never heard of Mr. Christofilos or his suggestion, discovered independently after much high-powered labour that such a system would indeed work. What Mr. Christofilos had discovered was the principle of the strong focusing synchrotron.

The story came to the attention of a number of leading U.S. physicists this year and created considerable interest in its hero. Christofilos, born in Boston, Mass., in 1916 of Greek parents, grew up in Athens, to which his family returned when he was a boy. He was educated as an electrical engineer in Athens and after graduation worked for an elevator manufacturer. In his spare time he studied atomic physics, and on his own he seems to have discovered the principle of the synchrotron itself. Then it

occurred to him that the magnetic field which keeps the accelerated particles in their path might be split up into a series of alternate focusing and defocusing sections which would have a strong net focusing effect and keep the particles in a very narrow beam. Christofilos had no training in mathematical physics, but he improvised a crude mathematical handling of the problem which gave approximations close enough to satisfy him that the idea was sound. Christofilos, now back in the U.S., has recently talked with physicists at Brookhaven and the University of California —and received a respectful hearing.

It would certainly be most interesting to hear about other recent cases where the virtual amateur has made a real and substantial contribution to scientific progress. Inevitably such incidents must be very rare these days, and the chances that they will receive any attention at all are rather slim for the whole mechanism of scientific publication and publicity is geared to the work of specialised professional scientists, and an amateur's discovery is lucky if it achieves recognition in print.

SCIENCE IN AUSTRALIA

The nineteenth century was nearly over before science teaching and scientific research had really begun to get started in Australia. In physics, for example, there was little of either before Sir William Bragg went out from Cambridge to take charge of the physics department at Adelaide University in 1886. The physics school at Melbourne University did not get into its stride until about the same time, following the arrival of Sir Thomas Rankin Lyle.

In those days it was no easy matter to find first-class scientists in Europe who were prepared to go to Australia and start new university departments in scientific subjects. Moreover, the development of Australian science was retarded because the best of the science graduates which her universities were producing all wanted to do post-graduate research in Europe where they could learn details of the latest techniques and theoretical advances: once they had made themselves at home there, they tended to stay in Europe, for there they found themselves working in laboratories which were making scientific history.

In short, science was slow getting started in Australia, and even when the universities had established their science schools and were turning out graduates in fair numbers the development of the research side of their activities was checked because so many of the best students went abroad for post-graduate training and never returned to their homeland to work.

That was the situation at the beginning of the century, but even today many Australian scientists believe that the research effort in Australia is much smaller than it ought to be. The present state of Australian science, and the future trends which need to be fostered so that the research effort can be expanded in a balanced fashion, are matters that concern not only Australia but the whole of the British Commonwealth. For the Commonwealth as a whole needs scientific assistance from Australia in such fields as

defence science (the Australians are deeply involved in guided missile research, for example, while Australian scientists took a quite prominent part in the Monte Bello atom bomb tests). Many of the scientific problems arising in the implementation of the Colombo Plan must go unsolved unless the Commonwealth can have the benefit of special knowledge and skills possessed by Australian men of science.

A book which will be found most informative by all who are interested in the development of science in Australia has just appeared. This is entitled *Science in Australia,** and comprises the proceedings of a seminar organised by the Australian National University of Canberra on the occasion of the jubilee of the Commonwealth of Australia and held in July 1951. In this volume one finds a number of distinguished speakers describing how the various sciences have developed in Australia, and also reviewing the leading problems which confront their research workers. Their concern is not primarily with the achievements of Australian science, but with the way Australian science is organised, financed and so on, and with deficiencies in organisation and how these could be rectified.

A good deal of attention is devoted to the Commonwealth Scientific and Industrial Organisation—the CSIRO for short—which is Australia's counterpart of Britain's DSIR, and which has made the pace for Australian science in general. Just after the First World War the Commonwealth Government started an Institute of Science and Industry. This body, with a small annual grant (never exceeding £30,000), provided a mechanism whereby senior scientists in the universities or Government departments could supervise the investigation by junior workers of industrial problems. In 1926 the Institute grew into the

* Science in Australia. Published for the Australian National University, by F. W. Cheshire, Melbourne: published in London by Angus and Robertson, price 30s.

Council for Scientific and Industrial Research, which was reorganised and became the CSIRO in 1949.

The CSIR and the CSIRO both have great achievements to their credit. According to a statement in *Science in Australia*, it outshone the universities completely in both fundamental and applied science before 1939. One of the reasons for this was that the Organisation had far more money at its disposal than the universities (which are largely financed by the separate states and not by the Commonwealth Government) and was therefore able to offer good salaries which attracted many of the best of Australia's science graduates, who knew they would also enjoy the advantage of a more lavish supply of good equipment.

The men at the head of the CSIRO did, however, recognise the essential need for the universities to develop if they were to train effectively the students, from among whom future CSIRO staff would be recruited. One way in which the universities gained financial benefit from the CSIRO arose from the practice whereby CSIRO Divisions were established within university precincts; in return for the university land and other university facilities put at their disposal the CSIRO made cash payments, and the universities also had the benefit of access to first-class equipment in the Organisation's laboratories. An example of this arrangement is provided by the National Standards Laboratory built in the grounds of Sydney University.

Sometimes the CSIRO has gone further to assist universities. For example, it has financed university chairs in special subjects, and has done so without having in view any direct benefit. Thus the Organisation put up the money which enabled Adelaide University to establish a Chair of Plant Genetics; the objective was an increased supply of trained geneticists, some of whom would later join the Organisation. At Sydney University two animal geneticists on the CSIRO staff have been attached to the University's Zoology Department. One speaker in the seminar particularly stressed the great importance of joint arrangements such as this between the CSIRO and universities. There is, it seems, an acute shortage of certain types of specialist workers, and this shortage can only be circumvented by literally sharing the services of individual workers between CSIRO and a university; under such a scheme the individual CSIRO staff man attached to a university devotes some of his time to seaching work, and spends the rest of his time on CSIRO research. Alternatively, a university professor may take on the task of directing a CSIRO research station in addition to his university duties. This has happened in the case of the Sheep Biology Laboratory just started at Prospect, near Parramatta, N.S.W. Prof. C. W. Emmens has been put in charge of this laboratory, but concurrently he continues his work as Professor of Physiology at Sydney University.

The industrial research done by CSIRO is organised on a substantial scale and reaches a high standard. But in general it is concentrated on long-term problems. Of the more short-term research, which can be done most effec-

tively inside industrial firms, there is not enough, however. Australian industry sponsors very little research, and most of its so-called research laboratories are nothing more than process control laboratories. This is largely due to the fact that a high proportion of Australian manufacturing firms are subsidiaries of overseas companies, and import processes and designs which have already been perfected in the factories of the parent companies. This may be a logical and proper way for new industries to be introduced into Australia, but the book points out that too much reliance on foreign industries for research and development spells danger, particularly in times of war or of economic upheaval. The participants in the seminar were unanimous that Australia must do much more industrial research. One-sided importation of 'know how' and research results can only lead to Australia getting information that is either obsolete or obsolescent. Things would change very much for the better if Australia had technological information of her own which she could exchange with other countries, for the information she would receive in return would almost certainly prove to be more up to date than she has received in the past.

The seminar came to a very emphatic conclusion on this matter: "Australian industry can never be more than a pale shadow of industry in other countries unless it puts its house in order and recognises that it must devote an increasing part of its resources to research and development," it decided.

As was mentioned earlier, the CSIRO does research of industrial significance, but it concentrates on long-term research rather than on work with immediate applications in industry. Its connexion with industry is rather less direct than that of Britain's Research Associations, and several speakers favoured the idea of establishing Research Associations on British lines. They believed this would be the best way to take care of scientific problems requiring research which arise in small firms. (There is, however, another school of thought which argues that the prime need is to persuade more small firms to employ scientists; the proportion with no scientific staff at all is far higher than in Britain, and the argument concludes that it would be putting the cart before the horse to set up Research Associations before the small firms are in a position to apply the results of research.)

One brand-new feature of the Australian research scene is the organisation which promoted the seminar—the Australian National University. This is no ordinary university, being designed to concentrate on post-graduate research. The fields in which its four main research departments will operate are, respectively, medical research, physical sciences, social sciences and Pacific Studies. The calibre of its staff is indicated by one example; the scientist in charge of its School of Physical Sciences is the brilliant and vigorous Prof. M. L. Oliphant. When this institution gets into its stride, and this is bound to take several years, it is bound to become a valuable pacemaker for Australian science as a whole.

RADIO-ISOTOPES IN MEDICINE

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One can draw no hard and fast line between biology and medicine. Medicine is a biological science. To the biologist are relegated many of the fundamental problems of medicine. Consequently it would be all too easy to re-trace in this article ground which was covered in my previous article, "Radio-Isotopes in Biology" (DISCOVERY, August 1953, pp. 256–9).

To avoid this I am arbitrarily confining the present article to aspects of radio-isotopes application in the clinic and operating theatre. Such limitation of subject matter has the added merit of permitting fuller attention to items in the narrowed field.

Just as clinical medicine itself broadly falls into the two categories of diagnosis and treatment, so the medical uses to which radio-isotopes have been put may, for convenience, be categorised as diagnostic or therapeutic. In general, the isotopes of medical importance serve dual roles. That is, the same isotopes serve both to diagnose and to treat, the differentiation lying in the doses in which they are given. In small quantities—i.e. just sufficient to permit their detection in the body by their radiations— they are used to diagnose certain conditions and ailments. In larger doses, such that their radiations are sufficiently intense to affect tissue metabolism, they are used to alleviate or cure.

Of the half-thousand and more available isotopes, only a dozen or so have so far found any real application in medicine. To be useful for medical purposes a radio-isotope must have certain essential properties. Perhaps the most important is a half-life suited to the job it must do. In no case must the half-life be so short—i.e. a matter of minutes—that the element has lost virtually all its activity in transit between pile and clinic. On the other hand, radio-isotopes which are to be used internally should have half-lives reckoned in hours or days and/or be of a species which is rapidly excreted from the body. Once a radioactive element enters the body there is no possible way in which its radiations can be altered or its decay hurried. Unless the isotope's half-life is sufficiently short so that radiation is reduced to a negligible amount within a reasonable time, or its elimination is so rapid that it quickly becomes quantitatively insignificant, a radioactive element can play havoc once it gets inside the body. The inexorable radium-induced necrosis that afflicted early workers in the luminous clock-dial industry drives home this point.

A radio-isotope must also be suited to its job in respect of the type of radiation it sends forth. Thus, a gamma-emitting isotope is required where an intense barrage of penetrating rays is essential, as, for example, in a tele-therapy unit for irradiating deep-seated tumours, or where discrete implants of the substance must irradiate some depth of surrounding tissue. A gamma-ray isotope is also needed where it is to be used diagnostically in such manner that it must be located through overlying tissues. On the other hand, the isotopes with feebly penetrating beta- and alpha-rays may be the ones of choice where strictly circumscribed action is desired—either for local treatment or for sharp delineation of a tissue or tumour for diagnostic purposes.

The place of the isotopes in medical therapeutics is largely, as might be expected, among the neoplastic diseases.* For many years it has been known that the rapidly dividing cells of cancerous tissues are particularly susceptible to irradiation. When it became apparent that the atomic age was bringing with it an abundance—one might almost say a glut—of radioactive forms of the elements, there were high hopes that these radio-isotopes would prove the 'magic bullets' in the fight against the cancers.

These early hopes have not been realised. It might almost be true to say that as a general weapon against malignant tumours the radio-isotopes have so far been disappointing. But in some specific forms of cancer they have given blessed relief: in a few they have even achieved what seem to be cures. With so intractable a set of diseases as the cancers even small mercies are gratefully welcome, and viewed in this light the radio-isotopes must be accorded a position of honour in the armoury of cancer treatment.

There are three ways in which radio-isotopes can be brought to bear on cancers. Firstly, they can be used to attack the malignant cells from sources outside the body. Secondly, they can be implanted in the tumour itself and the surrounding tissues. And lastly, in soluble form, they may be injected or taken orally; in this case one relies upon the cancer cells to pick up the radiologically active material from the blood stream. In the latter case, the attack may be either general or selective. A general radio-isotope, such as radio-sodium (Na^{24}), permeates all the tissues in the body, the hope for therapeutic effect lying in the greater vulnerability of the actively dividing cancer cells to radiation. The use of selective radio-isotopes seeks to capitalise on the predilection of some substances for specific tissues. In this way an attempt is made to build up a higher concentration of radiation in the pathological tissues than in the normal tissues.

RADIO-COBALT

Of the radio-isotopes used as external sources of gamma-rays, radio-cobalt (Co^{60}) undoubtedly heads the list. Radio-cobalt is in many ways a remarkable isotope.

At Harwell, tiny cylinders of ordinary metallic cobalt, about half an inch in diameter and half an inch long, are placed in the pile, where they are bombarded by neutrons. After some months they emerge as Co^{60}, and each one shoots forth gamma-rays equal to that of several hundred thousand pounds worth of radium! These mighty midgets of radio-cobalt, the rays from which are as powerful as

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* Neoplastic diseases are those caused by excessive growth of tissues—i.e. the cancers.

that from a 2,000,000-volt X-ray machine, can then be used to bombard deep-seated tumours with their cancer-killing rays.

The Canadians pioneered this use of radio-cobalt and they now have extremely powerful cancer-killing radio-cobalt teletherapy units in clinical use. A piece of cobalt (weighing little more than an ounce) which has been 'cooked' in the atomic furnace makes up the working portion of the radio-cobalt 'bomb', as the machine has been nicknamed from the appearance of the foot-thick lead case in which the intensely radioactive cobalt core is housed. The intense gamma radiation is aimed at the cancerous tissue through a small, shuttered opening in the lead case, and the method makes it possible to treat all forms of deep cancer with an absolute minimum of damage to overlying tissues.

Radio-iridium (Ir^{192}) has been used in a similar manner. A radio-iridium teletherapy unit, producing radiation equivalent to 20 grammes of radium, has been in routine operation since May 1950 at the Radiotherapeutic Centre of Addenbrooke's Hospital, Cambridge. On the whole, though, radio-iridium is inferior to radio-cobalt for cancer irradiation. Its gamma-rays are only as powerful as the filtered rays from an 800,000-volt X-ray unit, and its half-life is only 75 days, as compared with $5\frac{1}{4}$ years for radio-cobalt. The high-energy gamma radiation from radio-tantalum (Ta^{182}, half-life 117 days) also has possibilities for teletherapy.

Cancers which are accessible can be treated by direct application of a radioactive isotope. If the cancer is superficial, radio-isotopes may be applied as a surface dressing. Otherwise implants or instillations of suitable radio-isotopes may be used.

For topical application* radio-phosphorus (P^{32}, half-life 14·3 days) is ideal. It emits weakly-penetrating beta-rays,

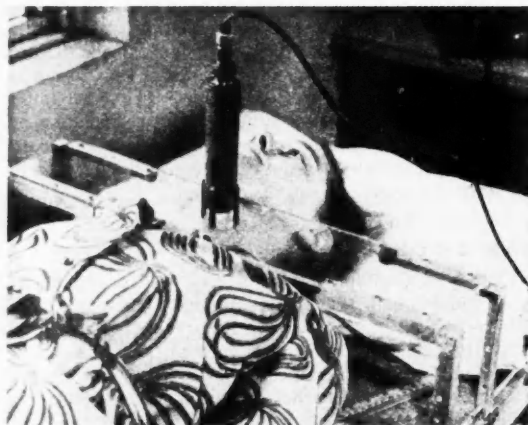* i.e. application to the surface of the body.

FIG. 1. Equipment used to determine the distribution of radio-iodine in the thyroid gland. A radiation 'map' is obtained by plotting the radiation intensity recorded by the Geiger counter when it is moved from point to point on the perspex bridge which has been ruled with squares.

which confine their activity almost exclusively to the cancerous tissues to which they are applied, sparing the normal tissues beneath and around the tumour. The method is simplicity itself. Ordinary blotting paper is impregnated with a measured dose of radioactive phosphate in solution. When dry, it is cut into the size and shape of the tumour area, sandwiched between two sheets of cellophane and strapped over the tumour with adhesive. In Germany radio-cobalt in the form of a fine metallic powder has been mixed with a doughy substance and moulded into the right shape and size for application to skin cancers (Fig. 2).

Many accessible cancers yield best to radioactive material implanted within them. Formerly they were treated with radium needles and radon seeds. These have their disadvantages. They are inflexible. Radium has a long half-life, so the needles must be removed after a time. If accidentally liberated in the body, it lodges in the bones and causes necrosis. Radon has a short half-life and cannot be re-activated. It goes to waste if not used in good time.

Several radio-isotopes are rapidly replacing radium and radon for implantation. They have specific advantages. Radio-cobalt can be drawn out as a wire or formed into tiny beads. Enclosed in tubes of nylon thread it can be inserted as sutures wherever a needle can reach, snipped and removed when its job is done. It has a long half-life and can be re-activated when old. Radio-gold (Au^{198}), which has a half-life of under 3 days, is inert in the body tissues. Therefore, it can be inserted and forgotten. If not used at once, it can be re-activated in the pile. It can be machined into grains much smaller than radon seeds; the grains can be fired right into the cancer from a 'gun' which holds sixteen of these radio-gold 'bullets'. Radio-tantalum has its claim to prominence, too. It can be drawn into a flexible wire, snipped in any desired length. It, too, is completely inert chemically in the tissues.

The chemical inertness of a number of the radioactive metals and their oxides has opened up a new type of implantation never before possible. They may be given as 'injection implants'—i.e. direct injection of a suspension of colloidal particles of the radioactive material into and around the tumour. Being insoluble and particulate, they remain localised at the point of injection and concentrate their action on the cancer cells. Radio-gold is ideal for the purpose.

For treatment of cancers on the walls of hollow structures, solutions of the salts of radioactive elements are often instilled into a closed elastic container inserted into the organ. Radio-cobalt chloride and salts of Na^{24} and radio-bromine (Br^{82}, half-life 35 hours) are available. Each of these elements sends out beta- and gamma-rays. When the linings of the chest or abdominal cavities have been attacked by cancer a colloidal suspension of radio-gold is most useful.

What are the practical effects of the radio-isotopes used in these ways? They are many. The surface application of radio-phosphated blotting paper has proved a boon in the obliteration of disfiguring cavernous angiomas in infants and children. The lives of sufferers of inoperable prostatic cancers have been made more bearable by injection implants of radio-gold. Advanced cancers of the cervix have

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been similarly controlled. Radio-gold has been credited with the supreme advantage over radium and X-ray therapy of rarely causing irritation of the neighbouring bowel and bladder. Inoperable tumours in other sites have also shown some response to injections of radioactive colloids.

Tumours of the urinary bladder may be treated by implantation of radio-gold 'bullets', or wires made from radio-gold or radio-tantalum may be woven into the cancer. If the lesions are multiple and superficial, the treatment of choice may be the instillation of radio-sodium or radio-bromine solutions into a balloon catheter inserted through the urethra.

The foregoing radio-isotopes, apart from radio-phosphorus, are all essentially gamma-ray emitters. The use of pure beta-ray radio-isotopes in needles and seeds for implantation has not yet been developed to a great extent. For such use they have potential advantages over the gamma-ray isotopes. Dr. J. S. Mitchell, Cambridge University Professor of Radiotherapeutics, lists these possible advantages as: "better dosage distribution, localisation of the radiation field, and ease of protection".

Colloidal radio-gold has in many cases proved a godsend to victims of cancer on the chest and abdominal linings. Cancers on the pleura and peritoneum are painful and incapacitating. The irritation of the tumours causes effusion and collection of large quantities of fluid in the chest or abdominal cavities. Now suspensions of colloidal radio-gold are injected into the cavities and often give most welcome relief. "About half the patients treated have received benefit from the treatment by a slowing down or temporary complete cessation of fluid formation, and I feel that the method is a useful palliative one in this late and distressing stage of malignant disease", Mr. R. J. Walton, Royal Cancer Hospital radiotherapist, has reported.

So much for the non-specific, generalised attack on accessible cancers. There is another method of cancer attack that is more specific in nature. It is the one which relies on the predilection of certain elements for certain tissues. At one time it was hoped that radio-phosphorus might fill the role of anti-cancer cell specific. This hope was based on the fact that actively dividing cells—which cancer cells are—build up large quantities of phosphorus-rich nucleoproteins. It was thought that in the process the cancer tissues might selectively concentrate the beta-ray-emitting radio-phosphorus and so treat themselves to a suicidal dose of radiation, without harm to neighbouring tissues.

As a general anti-cancer weapon radio-phosphorus has proved a dud. But in one specific condition it seems to be living up to theory. That is in *polycythaemia vera*—a disorder in which the body tissues that form red blood cells run rampant and clog the blood vessels with hordes of red cells. There is a sense of fullness in the head, dizziness, flushing. Thrombosis and haemorrhage threaten the life of the patient. In the past repeated bleedings and or chemical destruction of the formed red cells had to be resorted to. Now cases selected as suitable are injected with radioactive phosphate solution. (It may be given by mouth.) Such treatment does not produce cures of this

chronic disease—nothing does—but "satisfactory remissions of 12 to 18 months appear to be common", says Prof. Mitchell. And the treatment may be repeated. For the patient, life becomes more pleasant—freed as he is from his symptoms.

In the leukemias—i.e. cancers of the tissues forming white blood cells—radio-phosphorus has not done so well. Now and again a good result has been reported, but generally it has been a tale of remissions and failures. Radio-sodium has eased the suffering of some leukemia victims, but it, too, cannot be regarded as a successful attack on this class of blood cancers.

One might expect, on theoretical grounds, that radio-calcium might be selectively absorbed by bone tumours. In practice no promising results have been obtained. Nor has its near cousin, radio-strontium, proved of any use. More promising has been radio-gallium, shown to have 20 times the predilection for bone cancer as for normal bone tissue. It has given relief from pain in some cases. With a half-life of only 78 hours it can be given with a large degree of safety.

An unexpected case of selectivity is that of thorium C, a bismuth isotope, for bronchial cancers which have broken away and lodged in the skin. The radio-bismuth has produced temporary arrest of such tumours.

And then there is radio-iodine, I^{131}, half-life 8 days, in a class by itself among the radio-isotopes. It is the one really successful specific radio-isotope, and its principal success is outside the field of cancer.

As would be expected, radio-iodine has a predilection for the thyroid gland, which sops up iodine for incorporation into the hormone, thyroxine. In some people the thyroid gland throws off its controls and churns out thyroxine at a phenomenal rate. The result is thyroxine poisoning—i.e. thyrotoxicosis: nervousness, irritability, loss of weight, protrusion of the eyes, racing heart. Thyrotoxicosis is difficult to control. Drastic removal of large portions of the over-active thyroid gland is often performed. Anti-thyroid drugs, such as thiouracil, are used in an attempt to keep down the thyroxine output of the gland. Neither of these measures is wholly satisfactory. There are many relapses, and many undesirable side-effects.

In 1942 radio-iodine was brought into the picture. From the start it was highly successful. Its use was rapidly extended, particularly to people who had relapsed after thyroid surgery and/or no longer responded to the anti-thyroid drugs. The radio-iodine is simply given as a 'drink' in a glass of flavoured water. Within two to four weeks improvement begins to set in, and is completed in 70–90% of patients after the single drink. Most of the others usually respond to a second or third drink. In the treatment of thyrotoxicosis nothing as dramatically effective and impressive in its simplicity has ever been known.

But, while an outstanding success in the treatment of thyrotoxicosis, radio-iodine has scored only a very minor success against thyroid cancer. This is not so much the fault of the radio-iodine as of the cancer itself. Most thyroid cancers, particularly when they spread to other parts of the body, lose their ability to concentrate iodine. Consequently radio-iodine introduced into the body does

not lodge in the cancer and is unable to focus its radiation on the tumour cells. But about one-quarter of all thyroid cancers do concentrate radio-iodine, and among this group some spectacular successes have been chalked up by radio-iodine therapy. These have usually been cases where the cancerous thyroid tissue had spread to other parts of the body—skull, lungs, ribs, spine, pelvis—and the situation was desperate. Nonetheless, five-year cures—the criterion of successful cancer therapy—have been achieved with radio-iodine.

The foregoing is a fair picture of the current position of

FIG. 2. Treating a skin cancer with the plastic radio-cobalt preparation. The second picture shows the material in position over the cancer; it has been moulded to the required shape, and is wrapped in cellophane to avoid direct contact with the patient's skin. The third picture shows the result after two months' treatment.

the radio-isotopes in medical therapy. Apart from one or two fields in which they have achieved notable successes, the radio-isotopes have not, thus far, attained a pre-eminent position in medical practice. But it must be remembered they are relative newcomers to medicine. Their history spans a bare two decades, and is largely concentrated in the last 10 or 12 years. They are not without their dangers and the medical profession has, wisely, moved cautiously in their application. Very often they have been called in when all else has failed and death seemed inevitable. There is a reasonable hope that more experience may bring a greater degree of success to radio-isotope therapy. The current position has been nicely summed up by Dr. E. E. Pochin, U.C.H. Medical School Director of Clinical Research: "The radioactive isotopes now offer methods of proved clinical value . . . (and) certain of our patients will be inadequately treated or examined, if we do not make appropriate use of isotope methods."

Reference to the place of radio-isotopes in the examination of patients brings us to the diagnostic use of these radioactive elements. Radio-iodine again springs to the fore. Its selective concentration by functioning thyroid tissue makes it most suitable as a check for the level of thyroid activity. Over-active thyroids naturally take more iodine out of, and throw more thyroxine into, the blood stream than do normal or under-active glands. As the thyroid does not distinguish between iodine and radio-iodine and as the latter can readily be detected and measured by a gamma-sensitive counter, it is possible to employ radio-iodine in the assessment of thyroid activity (Fig. 1).

A standardised radio-iodine drink is given to the patient, after which the amount taken up by the thyroid gland and the amount returned to the blood in the form of hormone can be determined. This will usually establish a diagnosis in borderline cases of thyrotoxicosis, in which the mildness or inconsistency of the clinical signs makes diagnosis otherwise difficult and doubtful.

The radio-iodine test has the advantage of simplicity and recently it has been shown that it can be carried out on patients who live some distance from a radio-isotope laboratory. Forty-eight hours after a radio-iodine drink a small quantity of the patient's blood is collected and the plasma dispatched to the nearest radio-isotope laboratory by public transport. The diagnosis comes back by return post!

Thyroid cancers offer other problems and these, too, may be solved with radio-iodine. A test dose of the isotope will establish whether the cancer tissue is concentrating iodine and, therefore, whether it may be susceptible to radio-iodine therapy. If there has been spreading of the tumour to other parts of the body, a radio-iodine drink will locate these new sites in those cases where the daughter cancers are functioning thyroid tissue.

A more uncommon condition is 'lingual thyroid', in which a misplaced non-cancerous thyroid gland sits at the back of the tongue instead of at the front of the neck. Swelling of the gland causes distressing and, at times, perplexing symptoms. A sip of radio-iodine and investigation with a counter soon establish the nature of the swelling at the back of the tongue.

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The surgeon also benefits from the diagnostic application of radio-isotopes. Brain tumours are a notable example. Formerly to locate a brain cancer and establish diagnosis it was often necessary to fish inside the brain for bits of tissue for microscopic examination. But the degree of success from such "blind needling", one brain surgeon has stated, "was distressingly low". Radio-phosphorus has removed much of the groping from such diagnosis. Concentrated in the closely packed cells of the tumour, it can be detected by inserting into the brain a needle-like probe attached to a Geiger counter. As the beta-rays of radio-phosphorus travel only about one-fifth of an inch in normal brain tissue, it is possible to pin-point the position of the tumour —if one is present. After operation for removal of the tumour the surgeon can satisfy himself that he has removed all the cancer tissue by sweeping the field with a counter.

One of the principal concerns of a surgeon is the insurance of an adequate blood supply to the tissues with which he is dealing. Adequate blood supply is a critical factor in the survival and healing of tissues. Such is the case in the repair of a fracture of the neck of the femur. The head of the thigh bone, which is thus isolated from the rest of the bone, may have its blood supply cut off by the accident. When this happens the head of the femur is doomed to die. Surgical re-attachment fails and the condition deteriorates. By injecting radio-phosphorus into the patient's veins and observing the level of uptake in the head of the femur as compared with the bone itself, the surgeon can determine at the time of operation whether the blood supply to the head is adequate. In other words, he can diagnose the potential viability of the detached piece of bone. If the blood supply is unimpaired, he can pin the separated pieces of bone together with reasonable confidence in their ability to knit. Otherwise he must remove the femoral head and replace it with an artificial replica. Either way the chances

for a favourable outcome have been considerably enhanced by the use of the radio-isotope.

Grafting of skin from a healthy part of the body to an area which has been denuded also depends for its success on adequate blood flow to the tissues. By injecting radio-sodium into the skin being grafted, the surgeon can determine when its blood supply is sufficient at the implanted end to permit his cutting it free from its origin.

Perhaps one more example of the use of radio-isotopes in diagnosis will suffice to give some indication of the diagnostic potentialities of these agents. Radio-sodium injected into a vein at the ankle can clock the flow of blood in a leg. The clinician holds the counter at the patient's groin and notes the time it takes the radio-sodium to traverse the length of the leg. A delayed flow will inform him of the presence of some disease of the peripheral blood vessels which is impeding the flow of blood in the leg.

Such are some of the successes and failures of the radio-isotopes in the practice of medicine. Perhaps it will seem the failures are more spectacular than the successes. If such is the case it is only because we were led to expect too much from the radio-isotopes in the first place. Like an over-publicised movie starlet, the radio-isotopes have had to live down much of their advance publicity. Had their coming been attended by less ballyhoo, I am sure their record of achievement in medicine would today rank higher in the public mind.

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YOUNG TECHNOLOGISTS IN AMERICA

DR. J. BRONOWSKI

In this article Dr. Bronowski, who has spent four months at M.I.T. this year as Carnegie Visiting Professor, describes the special characteristics of the training given to students at that world-famous 'university of technology'. His account supplements the article which P. V. Danckwerts of Cambridge University's Department of Chemical Engineering contributed to our November 1952 issue.

Cambridge (Mass.) was given its name by the early settlers in Cromwell's day, to mark it proudly as the first university town in America. Today it is more industrial than Oxford (England). It is also more strikingly a university town, for it holds both Harvard and the Massachusetts Institute of Technology—which has become 'M.I.T.' to the world, but is still 'Tech.' to Cambridge.

These are large universities, but this is not what distinguishes them, for most States in America have larger ones. The University of Boston across the river, and the University of Massachusetts elsewhere in the State, are both larger. What distinguishes Harvard and M.I.T. is the standard which they set for their students. Young men come to them, as they come to Oxford and Cambridge,

from all over the country. They have the characteristic names of the American communities—Irish and Italian, Huguenot and Spanish and Pennsylvania Dutch. Each of my classes has also had students from South America and from Europe.

There are 5000 students at M.I.T., spread over four undergraduate and two graduate years. The yearly intake of freshmen is about 1000, and the competition for these places is ferocious. The Institute can therefore make ferocious demands on the students, and intellectually it does so.

Since the students are from schools scattered over a continent, the range of what one or other of them does not know when he comes still makes me blanch. This is a

problem common to all American universities, which most of them now meet (on the example of Harvard) by spending the first two undergraduate years on a general education in several faculties. But M.I.T. is not a general university: it trains only scientists, and for the most part applied scientists. The drive in the student to think of nothing but aerofoils or chemical engineering or electronics is therefore particularly strong.

M.I.T. meets this in two ways. First, it gives the undergraduate in his first two years an extraordinary grounding in all the sciences. You cannot become so much as a modest sanitary engineer here until you have first done the mathematics and the physics and the biology from which any true understanding of science must spring. *You cannot be a specialist until you are a scientist*: this is the axiom I found at M.I.T.

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Science is therefore treated here as a single body of thought and, in a sense, as a culture. This can be done only by having on the staff first-class men in all the sciences, however remote they may be from engineering. What strikes the visiting professor is the stature of the men working here precisely in, say, physics and biology. I have never spent my time with so many great men, endlessly and excitedly talking each other's shop, as in my evenings at M.I.T. and at Harvard.

This stress on fundamental science has its visible influence on all that the student does later in his lifetime work. I had supposed, before my visit, that American engineering development owes its success to the practical bent of the men who make it. And they are practical men; but their success rests on their strong *theoretical* grasp of what they are doing. The M.I.T. graduate, and the graduate from the other great institutes, does not approach a new piece of engineering with his hands but with his head. He begins with pencil and paper and with laboratory experiments: the laboratory work here, in all design problems, is most delicate.

I must underline this point because it took me by surprise. The English scientist breaks his heart because what he discovers never seems to travel from Oxford to Lancashire until it has first been developed in Chicago. What special gift has the engineer in Chicago? The answer I have found is that the young American engineer does not treat the scientist as a fool whose dream he has to knock into familiar shape. On the contrary, the engineer here wants to understand the discovery; he wants to develop it along its own logic; and he treats this task as an original science.

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I said that M.I.T. meets the odd ignorances of its freshmen in two ways. One is to show them science as a whole and as a culture. The other is to persuade them that,

nevertheless, science is not the whole of culture. Throughout his four years, the undergraduate must spend the equivalent of one day in each five-day week in the Department of Humanities.

This has been built up in the years since the war, in part to offset the scientific bias, and in part because most M.I.T. graduates in time move to directing posts in industry. The Department of Humanities makes the freshmen learn some world history and the seniors some economics; for the rest they can follow their taste in music, literature and any topic which fires a professor and his pupils together.

The stamina of the students, physical and intellectual, is remarkable; and the Institute exploits it without mercy. It believes that the good student can always learn more; and since it can afford to pick only good students, it gives them a heavy timetable and packs their leisure with reading. I found them sitting in the new music library, listening to the daily concert, while they clicked their slide-rules over their sums. They like modern music and some painting.

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To three-quarters of them, literature is a bore and writing a pain. The others read voraciously, from Shelley and Tolstoi to William Faulkner (who is not a well-known writer in America). Some of the students are learned in science-fiction, and most of them read it The most attractive exercise set in the Department of Mechanical Engineering this year was based on science-fiction. It presented each student with a large folder, dated about the year 2950, which described the birdlike and methane-breathing inhabitants of a mythical planet called Arcturus IV. The exercise was to design machines which the bird-men can use under the strange conditions of this planet.

I have no taste for science-fiction myself, which seems to me full of extravagance and empty of imagination. Part of its appeal to the students, however, is that it is a literature of dissent. It does not conform to the accepted standards of social success in America: its heroes are rebels and sometimes even liberals. Harvard and M.I.T. have been targets of Congressional investigation, for Congress does not like New England any better than Old England. But the committees have forgotten to censor the science-fiction.

I say this with wry relish, because I have met an official literary critic. When I landed in New York the policeman who looked through my trunks told me that under the McCarran Act he had to read all books brought into the United States. I encouraged him, and he picked up my own book on Blake. After he had read three or four sentences he looked at me in astonishment. "You write this, bud?" he said. "This ain't never goin' to be no best seller."

(*This article is published by arrangement with*
          "*The Observer*".)

THE NEW FILM TECHNIQUES

DENIS SEGALLER
B.Sc.

Stereoscopic films have come, decisively and finally; and '3-D' is a household word on both sides of the Atlantic. *B'wana Devil* will be remembered as the first stereoscopic feature film, as *The Jazz Singer* is remembered for being the first true sound film. And the birth-pangs of the new medium seem even more painful than the hideous noises of the early talkies.

Stereoscopic movies are indeed a new medium, and will need two things, as does every medium—the perfection of its own technical methods; and its own special craftsmanship. To us in 1953, bewildered and rather shaken by the sudden impact of the various new processes *en masse*, it may seem that technical perfection and craftsmanship must go even more closely together in this than in other media. We are too close to the beginning of it, too much involved in its novelty to make clear judgments yet; but it does seem as though the complaints and criticisms cannot always distinguish clearly between technical imperfections, and crude, unskilled handling of the medium. When we start trying to analyse our feelings after seeing a 3-D film, we find geometry, physiology, psychology and prejudice all entering into the argument—not to mention eye-strain.

THE TWO MAIN CLASSES

Many new processes for showing films have been talked about in the Press recently, but fundamentally so far only two broad classes of system have been invented (or at any rate, made public); classes, that is, that set out to do two basically different things. All known processes today fall within one or other of these classes, and vary among themselves only in the *manner* in which they reach their results.

CLASS I: TRUE STEREOSCOPIC SYSTEMS, IN WHICH EVERY MEMBER OF THE AUDIENCE SEES SEPARATE IMAGES WITH THE LEFT EYE AND THE RIGHT EYE.

(*a*) *Raster Stereoscopy*. Specially constructed screen with (originally) radial grid of black lines, or (later) radial system of conical plastic lens-elements, in front of screen. No spectacles or appliances are worn by the audience, but they must keep their heads still. Although the fundamental work on this system was done in other countries, no public presentations have been seen so far outside Russia. (See DISCOVERY, November 1949, Vol. X, No. 11, pp. 355–61.)

(*b*) *Systems where the audience must wear spectacles*. The spectacles discriminate between the two images, passing the correct image to each eye and excluding the wrong image.

(i) *Anaglyph method*. One image on the screen is in tones of blue or blue-green, the other in tones of red. The 'spectacles' are pieces of gelatin in a cardboard holder, red for one eye and blue-green for the other. The red eyepiece renders the red image invisible but allows the blue-green image to be seen by the eye in tones of black and grey; and vice versa for the blue-green eyepiece. Examples are the pre-war 'Audioscopiks' and its 1953 re-issue 'Metroscopics'. One or two other short films have also appeared. This system is apt to cause eye-strain and nausea due to the brain trying to fuse images in two different colours. It is of 'novelty' and 'stunt' value only and is unable to show scenes in colour.

(ii) *Polaroid Methods*. Left- and right-eyed images are projected through polarising filters whose planes of polarisation are at right angles to each other. The screen has to be made of non-depolarising material; metallised screens are found suitable for this purpose. The spectacles are similar polarising filters. Each eyepiece transmits only the correctly polarised image and completely blocks the other image. Systems at present using polarised projection methods include the British system of Stereo Techniques Ltd. developed by the Spottiswoode brothers, the several American systems starting with the pre-war Norling System and including Natural Vision (used in *B'wana Devil*), Paravision, Warner Vision and Stereoline, and Verivision, invented by Dr. Reijnders in Holland. (There are also a few sub-standard (16 mm.) processes for amateur or specialised use.)

Since these systems all belong to Class I and set out to do the same thing, the cameras and projectors used in all of them are interchangeable, in principle at any rate; it is only when the images have left the projector lenses and started on their journey to the audience's eyes via the screen, that the different methods are introduced for keeping the left- and right-eye images separate—polaroid filters or coloured filters in the projectors, or a raster screen, as in the Russian method. (In practice there are many differences of detail —some systems need two separate films and projectors; others manage with one film only, either by turning the pairs of images temporarily through 90 on to the film, side by side in reduced form, and then turning them back again in the projector, or else as in the Anaglyph system, by superimposing the two images, printing the red image on one side of the film and the green on the other.)

CLASS II: NON-STEREOSCOPIC METHODS GIVING A HEIGHTENED SENSE OF REALISM WITH FLAT FILMS, BY 'SURROUNDING' THE AUDIENCE.

(*a*) *Cinerama*. Three cameras are used to take three simultaneous films of the scene, each covering one-third of the field of view, the total field covered being 146 in azimuth and 55 in elevation. Three projectors then throw these images on to a curved screen 51 ft. wide by 26 ft. high, which virtually surrounds the audience. Enormously expensive to install and to operate, and will probably not be seen outside the U.S.A. for some time.

(*b*) *CinemaScope*. Does roughly the same thing, but more simply, by using a cylindrical type of compression

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lens (called a hypergonar) to squeeze a very wide angle of field on to the normal 35-mm. film frame in distorted form: a similar type of lens on the projector opens out the image again, fanwise, and throws it on to a screen approximately 60 ft. wide. Has already been demonstrated to the Press in Britain and two feature films shot on this process will probably be showing in London by the time this goes to press.

(c) *Wide-screen methods.* These just use a wide-angle projector lens to project a normal film image on to a huge screen. Top and bottom of frame are cut off by masking the projector gate, to approximate to the 'wide-screen' shape.

These systems are not stereoscopic because the image they present to the audience, colossal, breath-taking, or whatever it may be, is identical for both eyes. What is claimed is that they produce a kind of heightened reality with two-dimensional films not unlike the sensation of stereoscopic vision, due mainly to the stimulation of peripheral vision—that is, seeing things "out of the corner of one's eye". More will be said later about this class of system.

Surveying films in Class I so far shown in this country, what are the feelings one has retained, and what special things are remembered?
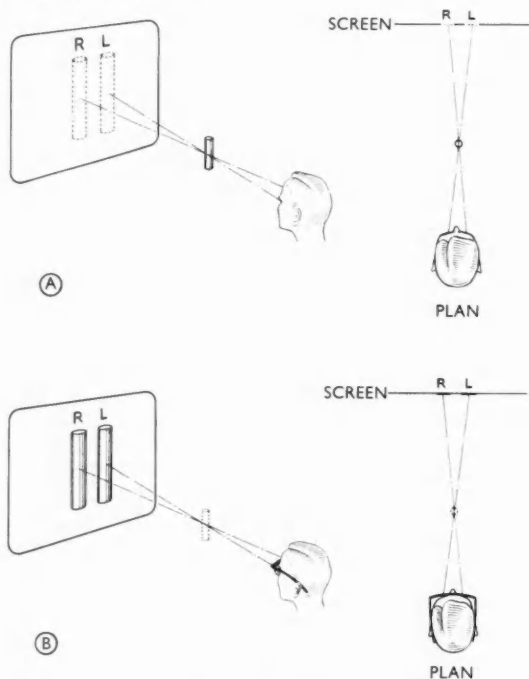

FIG. 1

(A) Spectator viewing a real, solid object situated in the auditorium of a cinema.

(B) Spectator viewing a stereoscopic pair of images on a cinema screen—seeing each image only with the correct eye by means of spectacles—and constructing from these images a single mental 'space-image' which he 'sees' at a definite position in the auditorium.

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First, it is fair to say there has been considerable disappointment and dissatisfaction with most of the films so far produced. They have, on the whole, lacked effectiveness both technically and artistically; they have failed to excite the imagination by exploiting the new sensation (new, at any rate, on the present large scale) of stereoscopy combined with movement and with film cutting. Apart from the two or three very delightful fantasies of Norman McLaren, 3-D has so far had hardly anything new or exciting to say. The pure novelty of having something dangling in front of one or thrust violently out from the screen has soon worn off, and such tricks have become slightly insulting to the audience's intelligence. On the other hand we have seen many shots which seem somehow to reach the other extreme; although very vividly 3-D, they might just as well have been 2-D for all we could care, for all the interest they arouse by selection of camera-angle and composition of the picture. Perhaps the nearest approach to a creative, dramatic use of the new medium so far has been the sequence in *The House of Wax* where the waxwork museum is on fire, and flames and smoke rise in the theatre in front of us, beams and walls crash towards us and even (so it seems from the stereophonic sound) behind us, and we almost start coughing and spluttering. But in most of the films one is left with the impression of what Richard Winnington in the *News Chronicle* calls ". . . the unnaturalness of a process that, through the polarised glasses, makes the players look smaller, foggier and more remote than in a nice comfortable flat film".

To try to approach one's feelings about 3-D films analytically involves, among other considerations, that of the 'space geometry' of an audience viewing, stereoscopically, images projected on to a large screen.

THE ESSENCE OF STEREOSCOPIC VISION

Fundamentally, what happens is this (Fig. 1). If there were a solid object stuck in the air between the viewer and the screen, and he shut his right eye, he would see with his left eye the object 'projected' against the screen at a certain position, slightly over towards the right; its apparent position on the screen would be where the line joining his left eye to the object, if extended, struck the screen. Correspondingly, with the left eye shut he would with his right eye see the object 'projected' on to the screen at a point slightly over to the left, where in fact the line joining his right eye to the object, extended, struck the screen. (This can be proved to oneself by holding a pencil up about a foot in front of the eyes and closing first one eye and then the other in succession, the pencil appearing to move from left to right and back again, against the wall behind.) Now if instead of these left- and right-eye views of the real object in space between viewer and screen, there are substituted two flat photographic images *on* the screen, *at the same places as the 'projections' of the real object*, and it can be arranged that each eye sees only its appropriate image, then the viewer's brain will do the rest: it concludes, from the evidence before its eyes, that there is indeed a solid object, stuck in the air between him and the screen, at the point in space where the lines from the two images to their respective eyes intersect. The *stereoscopic* image is, in fact, at
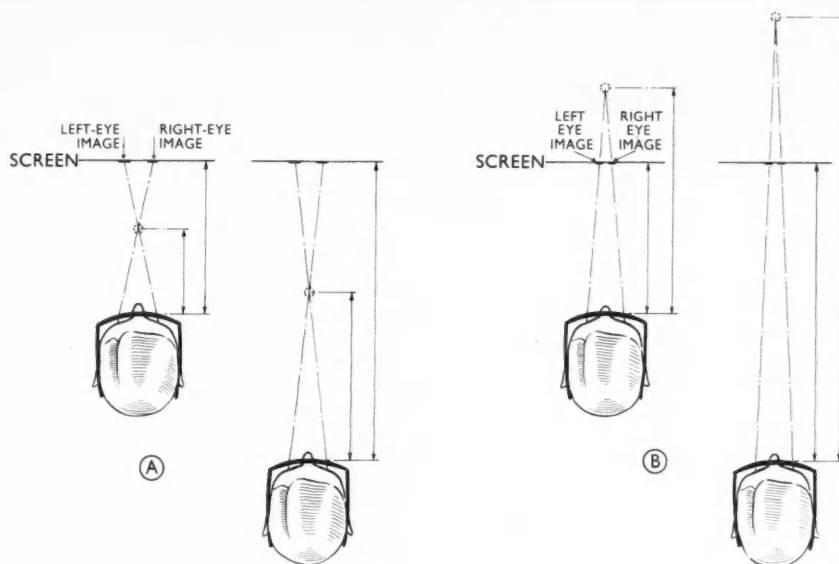
FIG. 2. No matter at what distance the specta-tor is seated from the screen, the distance of the space-image from him will always bear a con-stant ratio to his distance from the screen—whether the images are 'crossed over' as in A; or whether they are not crossed, as in B, so that the space-image appears behind the screen.

that point. This is the essence of stereoscopic vision.

It must, however, be realised that this stereoscopic image is only a 'space-image'; it is neither a 'real' nor even a 'virtual' image in the language of optics. One can only say theoretically, and from common-sense reasoning, that the image 'is' there at that point in space—a different point, of course, for every viewer since no two heads are in the same place. And the argument above is much simplified and ignores much of a physiological and psychological nature that is not yet fully understood. Stereoscopic vision is in many ways an intensively subjective phenome-non and can vary enormously from person to person, par-ticularly the extent to which they are aware of the very feeling of the third dimension. "That lion never came out in front of the screen at all." "Oh, it did with me—it was just in front of that woman's tall hat there."

Moreover, for most people there seems to be a certain time-lag, more or less, a period of adaptation before the brain becomes 'accommodated' or attuned to stereoscopic vision—rather like the time-lag in which the eyes adapt themselves for 'dark' vision when going suddenly into the dark, which also varies from person to person.* Some people can actually watch the stereoscopic image coming gradually out towards them while they look at it, and then click to a sudden stop when the brain 'sees' it in its geo-metrically correct place. It is like a gradual awareness of what hidden depths the picture really contains. It was for this reason that the producers of the 3-D film programme at the Telekinema at the 1951 Festival of Britain found it useful to start with an artificially made cartoon picture of banks of clouds at different distances from the audience, fresh clouds appearing nearer and nearer at a leisurely pace so that the audience's eyes and brains could get gradually acclimatised to the sense of stereoscopic vision.

* The two kinds of time-lag have, however, a very different origin —photo-chemical regeneration in dark adaptation and a mental process in stereo vision.

However, time-lag or no, there is a definite geometrical position in the space of the auditorium (or behind the screen) for a given stereoscopic 'space-image'; in other words, the screen images provide the viewer with data from which his brain can construct an unambiguous stereoscopic image. And this image, like the rainbow, is different for each viewer.

A very important fact can be stated about the position of this image. Consider first the special case where the left- and right-eye images on the screen are crossed over, as described above, and are separated by a distance equal to that between the viewer's two eyes (about $2\frac{1}{2}$ in. for most people). Clearly, the image will be exactly half-way be-tween viewer and screen. If he moves farther away from the screen, or nearer to it, the image will still be half-way; it will follow him all over the auditorium. And in general, when the distance separating the two images on the screen is either greater or less than that between the eyes, it can be very simply seen from the geometry of similar triangles that *the distance of the space-image from the viewer always bears a constant ratio to his distance from the screen, no matter where he is sitting in the auditorium.* This is just as true if the left- and right-eye images are not crossed over on the screen, so that the space-image appears behind the screen (see Fig. 2). (The theoretical limit is reached here when the images are the same distance apart as the eyes so that the eyes are looking along parallel lines and the space-image is at infinity.)

Using this simple mathematical relationship as a starting-point, the inventors of the British Stereo-Techniques system, the Spottiswoode brothers (who were the first to light upon the relationship), have worked out the complete mathe-matics of how a real 3-dimensional scene is recorded on film and ultimately projected in a cinema and seen as a space-image by the spectator;* their reasoning is partially

* See *Journal of the Society of Motion Picture and Television Engineers*, Vol. 59, No. 4, October 1952, pp. 249–86.

FIG. 3. Some of the factors controlling the distance (P) of the space-image from the viewer, in relation to the distance (p) of the original object from the camera. The magnification from film to screen is W/w.
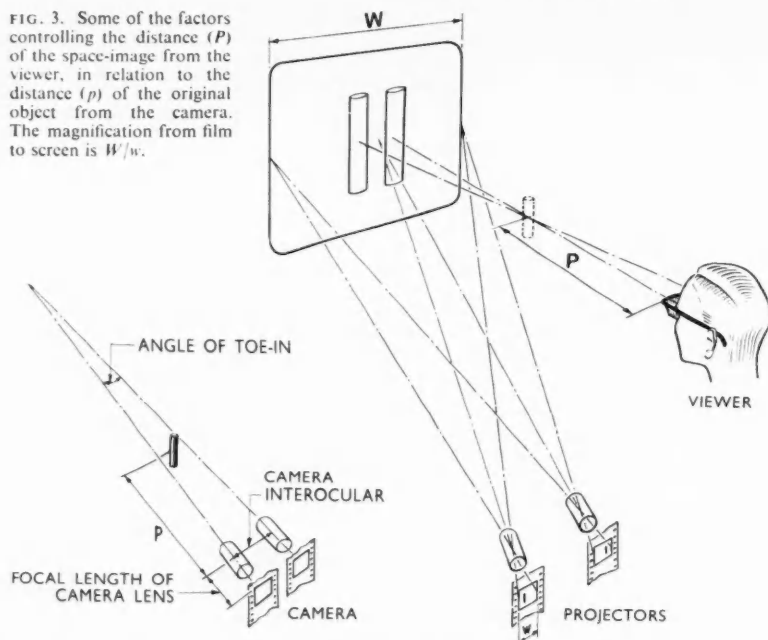
based on the earlier work of Professor John T. Rule in America. Before, however, trying to describe in words some of the deductions from this space-image geometry, it is only fair to stress again that physiology and psychology play a very major part in the appreciation of a 3-D scene, and the apparent distances of the various parts of the image may depend as much on the psychology of the situation and the association of ideas evoked by the picture, as on the rigid mathematical consequences of the paths of light rays to and from the screen.

The first fundamental equation the Spottiswoodes deduce is the general one relating the distance of the stereoscopic space-image from a given viewer, to the distance of the original object from the camera (see Fig. 3):

$$P = p \cdot \frac{A}{C - Bp},$$

where P is the distance of space-image from viewer;
p is the distance of object from camera;
A is a constant for each viewer, provided he doesn't change seats;
C is a constant—different for each shot in a film—dependent on magnification from the film to the screen, the focal length of the camera lenses, and *their distance apart, or 'interocular', varied to suit the needs of each shot during shooting*; and
B is a constant—different for each shot—dependent, among other factors, on *the 'toe-in' or convergence of the camera lenses*, also varied to suit each shot during shooting.

Thus the denominator of the fraction on the right-hand side of the equation contains a minus term itself involving

p, the distance of object from camera. This means that, in general, *distances of images from the viewer do not vary linearly with (are not proportional to) distances of the original objects from the camera.* °In other words, unless the term B is made zero, distortion of space is inevitable, and parts of the picture will appear squeezed up or stretched out relative to other parts.

If, however, B is made zero, then the distance of any space-image from the viewer becomes directly proportional to the distance of the object from the camera (though not, of course, necessarily *equal* to it; there will in general be a constant factor, greater or less than unity, by which all distances are stretched or shrunk).

B is a rather complicated term; it can be expressed more simply as: Difference between distance apart on the screen of the two images of a point which was at infinity in the original scene, and distance between the eyes.

(Thus if B is positive, the images of those parts of the original scene which were at infinity will be farther apart on the screen than the viewer's eyes: the eyes must actually *diverge* (or 'squint' outwards) in order to fuse the images. Our eyes can do this to a limited extent but it causes bad eye-strain.)

The Spottiswoodes regard all 3-D shots as falling into one of three categories—those where B is negative, those where it is zero, and those where it is positive:

Class	Name	Characteristics
$B = O$	Ortho-infinite	Linear; infinity points correctly represented
$B+$	Hyper-infinite	Non-linear; objects short of infinity represented at infinity
$B-$	Hypo-infinite	Non-linear; objects at infinity represented closer than infinity; cardboarding

(The expression 'cardboarding' is a very descriptive and obvious one and refers to an effect which many people will have noticed in 3-D films, in which the total depth of the scene is drastically telescoped and the various parts of the image, though separated in depth, appear flat in themselves instead of rounded—rather like cardboard cut-outs or stage scenery. The Spottiswoodes point out that this condition is often met with in amateur projection of stereo stills and movies, where shots of distant objects are taken with camera lens axes parallel and projected with projector lens axes toed-in so that the centre lines of the two images on the screen coincide.)

Thus, *if* the distortion-free representation of the original scene is what is required, the ideal to be aimed at is to

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make $B = O$. Leaving aside for the moment the considerations of that 'if', it must be realised that it is not possible to make $B = O$ in every shot. In some shots it has to be made positive, because of physical limitations in the design of most present-day 3-D cameras—that is to say, in such shots it is impossible to make the distance between camera lenses small enough to satisfy the equation, given the distances of objects from the camera and the positions required for their space-images in the cinema; so to compensate, B has to be made positive by altering the 'toe-in' angle of the camera lenses. And as we have seen, once B is positive, some depth-distortion is inevitably produced. Moreover, cinemas vary considerably in the size of their screens, whilst the film image is always of constant width (22 mm. for standard 35 mm. gauge film); so that a $B = O$ shot in one cinema will not necessarily be $B = O$ in another. The high degree of magnification from film to screen ($\times 150$ for a small 10-ft. wide screen, $\times 400$ for one of $27\frac{1}{2}$ ft.), coupled with the relatively small distance between the eyes, combine to make the stereoscopic impression of depth highly sensitive to, and dependent on, minute changes in the different variables—separation of camera lenses and projector lenses, angles of lens convergence in camera and projector, screen magnification, optical printing displacement. Put another way, the eyes are like a range-finder with a very small base, subtending a very small angle at the positions of the various space-images which form the scene; a minute change in the position of the images of the screen can cause a very large shift in the distance of the space-images from the viewer.

It appears from the Spottiswoodes' mathematics that for complete absence of distortion—that is, orthostereoscopy—the condition of perfect reproduction in which every point in the image is geometrically congruent with the scene it represents, and everything has exactly the same size, shape and position as in the original scene—three separate conditions are necessary:

(i) $B = O$
(ii) Separation of camera lens axes = separation of eyes
(iii) Viewer's distance from screen = (magnification from film to screen) $\times$ (focal length of camera lenses).

Thus for a given focal length of camera lens and in a given cinema, there is only one correct viewing distance. The Spottiswoodes deduce that in an average cinema with, say, a 20-ft. wide screen, if the scene extends to far distant objects (at infinity, for practical purposes) the nearest object to the camera cannot be nearer than 25 ft. for distortion to be completely avoided; thus only long-shots are possible.*
From this they infer that ". . . it may safely be asserted . . . that distortions are inseparable from stereo films—as indeed they are from flat films", and they have accordingly made a study of the "character and incidence" of such distortions.

As we have seen, these depth distortions are ultimately the consequence of the fact that images are being projected on to screens in commercial cinemas which are large relative to the film frame and to the distance between the eyes. This is rather a disturbing thought, and might seem at first

* Close-ups are, however, possible provided there are no distant objects also in the scene.

to have put paid from the word 'go' to stereoscopic cinema as a serious and permanent addition to the fields of art, entertainment or instruction—until one remembers that all successful visual art forms have flourished largely by making a virtue out of the limitations of their technique. After all, the distortion of ordinary 'flat' films is often put to striking dramatic advantage. It is only because of the added realism—often so vivid as to be quite startling—which 3-D brings, that we are apparently far more sensitive to distortion. If a way of using depth distortion to produce or heighten dramatic or other kinds of effect can be found, while avoiding unwanted irritating distortions, then 3-D films will come into their own and find their true purpose (as, for instance, the deliberate exaggeration of depth, or hyperstereoscopy, is put to good use in aerial survey work where stereo pairs of photographs of the ground from the air show the vertical dimensions of hills, valleys and other features enormously magnified, thus enabling contours to be plotted with a very high accuracy. This effect has yet to be seen in an air-to-ground shot on the cinema screen.)

One particular type of distortion very prominent in 3-D films so far, and due to B being positive and not zero, is that of the size and shape of objects—particularly the human figure, in whole or in part. The space-image of a given object has (for a given position of the viewer in the cinema) a fixed position in the space of the cinema, as we have seen; it has also a fixed, determinate size and shape. This size may be greater or smaller than that of the original object; also—as appears from the mathematics—the magnification of image relative to original object is, in general, *different* in the 'broadside' direction, that is, in planes parallel to the screen, from that in depth, from front to back. The formulae for 'width' magnification and 'depth' magnification—m_w and m_d in the Spottiswoode vocabulary —both contain terms involving the villain, B; but in m_d this term is squared, while in m_w it is only to the first power; so that the difference between m_d and m_w becomes greater the greater the value of B, whether positive or negative. The Spottiswoodes produce another concept, μ, the *shape ratio* (see Fig. 4), which is simply
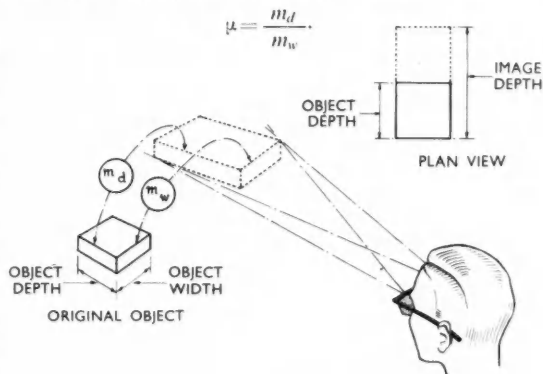
$$\mu = \frac{m_d}{m_w}.$$

FIG. 4. The concept of μ, the shape ratio of a space-image to its original object. m_d (depth magnification) equals image depth/object depth; m_w (width magnification) equals image width/object width. In the plan view shown, the image-depth is twice the object-depth, and μ is 2.

If B is positive, μ is greater than 1, that is, things look elongated from front to back. Since we tend to notice distortions in the human face much more than in inanimate objects, this accounts for the effect so often noticed in close-ups of faces—the sides of the head look too deep, the eyes look deep-set and the nose very prominent; while the head somehow seems to be some distance in front of the shoulders and body, as if it were stuck out forward on a hidden horizontal pole from the neck.

Even in the special case where $B = O$, the formula for μ becomes simplified, but μ is still not necessarily equal to unity, as it should be, of course, if things are to look their proper shape. To make $\mu = 1$, you must sit in the right place, given by a condition we met earlier, that:

Viewers' distance from screen = (magnification from film to screen) × (focal length of camera lenses).

At any other viewing distance objects will look either elongated or squashed up.

But even at the correct distance, with $\mu = 1$, the image, although now the right *shape*, is not necessarily the right *size*. The condition for this is the remaining one of the three we met earlier, viz:

Separation of camera lens axes = separation of eyes.

When this condition is *not* satisfied, the formula for m_w reduces to

$$m_w = \frac{\text{separation of eyes}}{\text{separation of camera lens axes}}.$$

This change in the size of the image in proportion as the camera 'interocular' distance is changed relative to that of the eyes can be explained in a simple way as follows (the explanation is adapted from A. W. Judge's book *Stereoscopic Photography*). If a stereo pair of photographs is taken of, say, a distant range of mountains with the camera lens separation equal to that of the eyes, then the result when viewed in a stereoscope will look roughly the same as in real life, that is to say there will be depth or relief in the foreground and middleground but none in the distance—the valleys, folds and ridges in the mountain range will all appear flat since there is no feeling of depth at distances of more than about 700 ft. away from us.* But to a giant 100 times our own size lying on his stomach the original scene would appear different—the mountains would appear 100 times nearer and 100 times smaller, and would have considerable depth or relief. We can imitate the giant with his eyes 21 ft. apart by putting our own camera 'eyes' 21 ft. apart instead of $2\frac{1}{2}$ in. The resulting stereo pair, when viewed in a stereoscope, will look like a model mountain range 100 times nearer and smaller, and with considerable stereoscopic depth.

This effect occurred very noticeably in some shots in one of the 1951 Festival of Britain programmes of films, where the use of two Technicolor cameras necessitated the camera

* That is, there is no 'feeling of depth' due to disparity of the left- and right-eye images (no stereoscopic effect). There are, of course, many other 'clues' to the third dimension in general (e.g. linear and aerial perspective, brightness and texture gradients, etc. and, most important of all in films, parallax of motion). The reader is referred for a full account of these 'depth clues' to Prof. J. J. Gibson's *The Perception of the Visual World* (Cambridge, Mass., Riverside Press, 1950).

'interocular' being several times larger than the distance between the eyes, owing to the physical size of the cameras.

DWARFISM AND GIANTISM

As a result, human figures looked like midgets no more than a foot or so tall. They were in fact, obeying the formula

$$m_w = \frac{\text{separation of the eyes}}{\text{separation of camera lenses}};$$

at the distance they appeared from the viewer, the space-images of these human figures were several times smaller than life. This particular kind of size-distortion has been christened 'dwarfism'.

Just as there is 'dwarfism', so also there is the opposite effect—'giantism', caused by taking a 'fly's-eye' view, with camera lens separation much *smaller* than that of the eyes. This should, according to the formula for m_w, make things look very big, and far away. This, too, has its uses in still stereoscopic work, especially for microscopy. If one wants to look at something very small one cannot see it stereoscopically by holding it very close to one's eyes—they can neither converge nor focus on it. So a microscope is used. To get a stereoscopic effect, however, we must turn ourselves into a human fly with eyes very close together. Stereo pairs of photomicrographs taken in this way produce the desired effect. So far this has not been done, to the writer's knowledge, with moving films—the optical system would no doubt present considerable problems; but it would be interesting to see a 3-D close-up of, say, the inside of a watch filling the space in the auditorium.

Strangely enough, the effect of 'giantism' in shots where the camera lens separation is appreciably less than that of the eyes, seems on the whole to be missing; the writer has never particularly noticed it in any 3-D films. It is as if one can accept a larger-than-life close-up that has solidity and roundness as part of one's normal film experience. But 'dwarfism' seems to be much more troublesome; it is an effect which many people, including the writer, claim to have noticed often in nearly all later 3-D films, both British and American. Yet, once this early error of technique (using a very wide camera 'interocular') was realised, it has seldom, if ever, been repeated in British 3-D films (the use of Monopack film for colour productions means that ordinary cameras can be used and there is thus no longer the physical obligation, due to camera bulk, to have camera lens separation larger than human eye separation). Indeed, as we have seen, the requirements of shooting and space-reproduction often mean having camera lens separation *less* than that of the eyes. How then are we to account for the frequently-seen effect of 'dwarfism'?

It seems probable that the answer is largely psychological. We have become so used to looking at huge close-ups of people, or even huge long-shots of people, in ordinary flat two-dimensional films, that when in a 3-D long-shot we see space-images of human beings *their correct size*, we imagine them by contrast to look smaller than life. This may be what was meant by the critic who complained of the actors looking "smaller, foggier and more remote" than in ordinary films. And after all, the amount of 'dwarfism' noticed varies, like all other stereoscopic sensations, greatly

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from one person to another, which seems to point to a psychological effect. Perhaps it is also caused partly by the feeling of looking through a comparatively small window in a huge black void, which one seems to get when watching 3-D films; for, apart from all other considerations, the effect one seems to remember most after seeing any 3-D film in any of the cinemas, has been that of *a screen that is in itself far too small for the medium*—except in the front stalls, where the picture is all squashed up in depth anyway. It is interesting to read in an eyewitness account by one of the editors of *Les Cahiers du Cinéma* for April, 1953, that in the Sterokino Theatre in Moscow, where the raster system is used and no spectacles are worn, the sensation of depth is just about the same as in the British system; the same qualities and the same defects are there—"an undeniable stereoscopic relief, but not really a world in depth. Branches of apple blossom come out and tickle our noses, but once we are in longshot, figures of people soon appear dwarfed."

Both 'giantism' and 'dwarfism', when they are real physical as opposed to psychological distortions, should obviously be avoided whenever possible since, as mentioned earlier, the added realism of 3-D makes us so much more sensitive to size and shape distortion than with 'flat' films. The exception, again, is where they are used deliberately to produce a calculated distortive effect for dramatic or other reasons.

This, then, is a summary of some of the mathematics of 3-D recording and reproduction as worked out by the Spottiswoodes in this country, and of some of the distortions, both physical and psychological; distortions which are to some extent inevitable and are (in the case of depth or shape distortion) mainly the result of projecting on to large screens, and which increase in magnitude with the size of screen. The work of Stereo-Techniques Ltd. has been based on the principle of a completely variable camera 'interocular' and angle of camera lens convergence, these factors being adjusted for each separate shot to suit that shot's particular requirements. In America, however, and among certain inventors in this and other European countries, there has been up to the present a strong conviction that the camera lens separation should always be kept equal to that of the eyes, the 'toe-in' or convergence of the lenses being always adjusted so that the axes intersect at the object of chief interest in the scene, as do the eyes when looking at an object. 'Natural vision' or 'human vision', as this principle is called, appeals to the idea that in imitating a physical human function by mechanical means, one should do so as closely as possible. But to quote again the Spottiswoode brothers: "The viewing of a stereoscopic image cannot at present be made to resemble human vision at all closely. The image in space is not even an optical image; it is a mental construction from data supplied solely by overlapped images on a flat screen. This construction is accompanied by methods not used in normal vision; for example, the spectator's eyes must remain focused at the screen distance, but they will be varyingly converged according to the distance of the point of attention, which may be much nearer or much more remote. Furthermore, in the real world, sense-data remain more or less constant when spectator and scene are fixed;

but stereoscopic data may be made to vary widely according to projection conditions, and indeed cannot be kept constant when the size of the screen is changed. It is therefore not to be expected that a mere reproduction at the camera of the human eye separation—in the absence of human viewing methods—will of itself produce strain-free viewing. This cannot be so simply achieved until it becomes possible to create real or virtual 3-D images in space."

It is perhaps the feeling of cinematic claustrophobia referred to above, of peering through a small window or hatch, common to all 3-D systems today, that has induced Hollywood to turn, for part of its assault on conventional movies, towards the second class of system, the 'big-screen' and 'wide-screen' systems. Stereoscopic or binocular vision, it is felt, is perhaps not everything in realism. The field of human vision is much wider than it is high—about 165° in azimuth by 60° in elevation—and is in any case much greater than that covered by the average normal cinema screen when sitting at the middle or back of the auditorium. Let us, say the sponsors of wide-screen, reproduce the size and shape of the field of human vision; let us expand the cramping boundaries of the narrow-angle conventional screen. Cinerama and CinemaScope, two ways of doing this, are certainly quite exciting and spectacular new kinds of entertainment; the huge, wide screen gives one the feeling of actually taking part in the scene on the screen, and there is a considerable feeling of realism. This is particularly noticeable when something is approaching fast—a train, for example; on an ordinary rectangular screen with a 'flat' film, the train would grow in size as it approached the camera, then finally disappear off the edge of the screen to left or right. In Cinerama or Cinema-Scope, however, the train, after approaching to its full size, darts off to left or right, but remains on the screen since the screen is so much wider; we follow its movement out of the corner of our eye, and it appears to be coming out alongside of us in the auditorium (not *at* us, as in a 3-D film).

But it is in the creative, aesthetic sense that these systems are really an unknown quantity. What form of film cutting will be possible when every longshot is its own close-up, since objects will often be already large enough to see in full detail? The wide screen will itself need its own new idiom—different from that of conventional flat films, and different again from 3-D, if it is ever to become anything greater than a showman's exhibit or a circus turn.

Logically, perhaps, what is wanted is the curved screen *and* 3-D; perhaps 3-D only in the centre of the screen, the peripheral regions being 2-D as they are apt to be in the field of human vision. "You'll see," said a French humorist, "they'll end up by inventing the theatre."

3-D films are in their infancy; the curved screen is only just born. It will take perhaps another two or three years for their novelty to wear off, for technical imperfections to be overcome and the relative claims of geometry and psychology to be sorted out; and probably much longer for their idioms and grammar to become established, and the best possible uses found for them. Only then will they be able to take their place with flat films, black-and-white and coloured, television, radio, theatre, ballet, filmstrips, wall-charts, text-books and the rest, as true media of entertainment and instruction.

JOHN DALTON AND THE REBIRTH OF ATOMISM

FRANK GREENAWAY

M.A., F.R.I.C.

JOHN DALTON (1766–1844).
(From portrait in Science Museum, South Kensington.)

On the night of October 3, 1803, ten men met in a room in Manchester at a meeting of the Manchester Literary and Philosophical Society to hear a paper by their secretary, John Dalton, on the solubility of gases in water. At the end Dalton added a few words which must have seemed almost irrelevant to the subject in hand, but which in fact marked one of the milestones in the history of science. Speculating on the reason why gases are not all equally soluble in water Dalton said, "I am nearly persuaded that the circumstance depends upon the weight and number of the ultimate particles of the several gases. . . . An inquiry into the relative weights of the ultimate particles of bodies is a subject, as far as I know, entirely new: I have lately been prosecuting this inquiry with remarkable success. The principle cannot be entered upon in this paper, but I shall just subjoin the results as far as they appear to be ascertained by my experiments." There follows a "table of the relative weights of the ultimate particles of gaseous and other bodies", the first table of atomic weights.

THE EARLY ATOMISTS

In this way Dalton fused the modern method of quantitative enquiry with the most venerable of all hypotheses of the constitution of nature. He did not originate the idea that matter might be considered as being made up of small indivisible particles—such an idea had first been propounded over 2000 years before by the Greek atomists, Leucippus and Democritus, as a philosophical attempt to reconcile the views of those who thought, like Parmenides, that change was an illusion, and the views of those who thought, like Heraclitus, that change was the only reality.

Dalton did not even revive the idea. After a long eclipse it had come back into philosophical thought in the 17th century. It had played a part in the thoughts of Descartes and Boyle, and a very important part in the thought of Newton. Throughout the 18th century, the corpuscular aspect of Newton's system of optics was the prevailing theory of light; corpuscular explanations of the phenomena of heat and of chemistry were commonplace, but were of little value in advancing scientific knowledge.

Dalton took the familiar atomic hypothesis, reduced it for the first time to a quantitative basis, related it in a simple deductive system to experimentally verifiable fact, and thus gave it the form and status of a scientific theory.

Fully to assess Dalton's achievement would take us deep into the history of science. Although his atomism resembled the atomism of antiquity in its deductive character, it differed from it profoundly in its power of quantitative prediction. Democritus saw as his duty the fashioning of a theory which would completely explain the material world. Epicurus wanted a complete materialistic scaffolding for an ethical and philosophical system. Lucretius aimed to describe the whole of nature in terms of the Epicurean atomic system. Quantitative measurement of parts of the world had no part in their thinking.

Dalton was a man of his times. It was enough for him to "pick up pebbles on the beach", like the Newton he so much admired and whose works formed an important part of his limited reading. He set out to explain some narrow range of phenomena which might be nevertheless, by its very narrowness, all the more amenable to numerical specification. The atomic theory set out in the pages of Lucretius was a 'universal' hypothesis in that its expositor set out to explain with its aid all physical phenomena and all spiritual experience. When the idea of an atom reestablished itself in modern thought in the 17th century, it did so as a modest aid to a natural philosophy which was already showing signs of specialisation and limitation of fields of study. It was inevitable that sooner or later someone would think about it in close relation to something that had been measured in an investigation into a limited problem. That is what Dalton did. His limited problem was the evident homogeneity of the atmosphere.

It is worth looking at Dalton's own words (taken from a lecture he gave at the Royal Institution in 1810) about how he had been thinking around 1800.

"Having been long accustomed to make meteorological observations, and to speculate upon the nature and constitution of the atmosphere, it often struck me with wonder how a compound atmosphere, or mixture of two or more elastic fluids, should constitute apparently a homogeneous mass, or one in all mechanical relations agreeing with a simple atmosphere. . . . Upon considering this subject it occurred to me that I had never contemplated the effect of difference of size in the particles of elastic fluids. By size I mean the hard particle at the centre and the atmosphere of heat taken together. . . ."

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His investigations led him to study the recently published law of Henry—that the amount of gas absorbed by water varies as the pressure. Dalton became interested and by studying the solubility of more than one gas at a time produced his law of partial pressures. Towards the end of his 1803 paper occur the following words.

"The greatest difficulty attending the mechanical hypothesis arises from different gases obeying different laws [of solubility]. Why does not water not admit its bulk of every kind of gas alike? This question I have duly considered, and although I am not yet able to satisfy myself completely, I am nearly persuaded that the circumstance depends upon the weight and number of the ultimate particles of the several gases; those whose particles are lightest being the least absorbable, and the others more, according as they increase in weight and complexity." After that passage came the proposition which I quoted in the first paragraph of this article, announcing the derivation of the relative weights of the ultimate particles of bodies.

DALTON'S QUANTITATIVE APPROACH

So in 1803 there appeared for the first time a confidently calculated assessment of a quantitative property of the hypothetical atom, *though the paper did not give the argument upon which Dalton based that assessment.*

Dalton soon presented that argument, however, in lectures which he delivered at the Royal Institution in London in December 1803 and January 1804, and at Edinburgh and Glasgow in 1807. It was put before a wider public in an account given in Thomas Thomson's *System of Chemistry* (1807). It became generally known after 1808, in which year Dalton published the first part of his *New System of Chemical Philosophy*. In this book Dalton confesses to the confused nature of his earlier thoughts, but shows how, once he was convinced that the atoms of different gases were of different sizes, it seemed desirable and possible to determine their *relative* sizes and weights. We can see quite clearly that he approached the idea, which is still the primary hypothesis of modern chemistry, not by chemical methods but by simple mathematical physics.

Here are first his grounds for belief in uniform atoms.

"Whether the ultimate particles of a body, such as water, are all alike, that is of the same figure, weight, etc. is a question of some importance. From what is known, we have no reason to apprehend a diversity in these particulars; if it does exist in water, it must equally exist in the elements constituting water, namely hydrogen and oxygen. Now it is scarcely possible to conceive how the aggregates of dissimilar particles should be so uniformly the same. If some of the particles of water were heavier than others, if a parcel of the liquid on any occasion were constituted principally of these heavier particles, it must be supposed to affect the specific gravity of the mass, a circumstance not known. Similar observations may be made on other substances. Therefore we may conclude that the ultimate particles of all homogeneous bodies are perfectly alike in weight, figure, etc. In other words, every particle of water is like every other particle of water: every particle of hydrogen is like every other particle of hydrogen, etc." (*New System of Chemical Philosophy*, p. 142.)

ELEMENTS

Dalton's symbols for the elements, 1806–7, as used in his lectures. (*From Science Museum photograph of original in possession of Manchester Literary and Philosophical Society.*)

The theory is also to rest on what we now call the Law of Conservation of Matter, a postulate which had no specific author, but had gradually come to be accepted as essential for the stability of chemical thought: "Chemical analysis and synthesis go no farther than to the separation of particles one from another and to their reunion. No new creation or destruction of matter is within the reach of chemical agency." (*Op. cit.*, p. 212.)

Then Dalton proceeds to give the reasons for his study.

"In all chemical investigations it has justly been considered an important object to ascertain the relative weights of the simples which constitute a compound. But unfortunately the enquiry has terminated there; whereas, from the relative weights in the mass, the relative weights of the ultimate particles or atoms of the bodies might have been inferred, from which their number and weight in various other compounds would appear, *in order to assist and to guide future investigations and to correct their results.*" (*Op. cit.*, p. 212. My italics.)

These words mark the turning point in the Chemical Revolution. Here Dalton is setting chemistry the task of quantitative prediction within the framework of a great unifying principle.

Dalton's numerical argument is very simple. He makes certain assumptions about the modes of combination of

atoms. "When only one combination of two bodies can be obtained it must be presumed to be a binary one, unless some cause appear to the contrary. . . . When two combinations are observed they must be presumed to be a binary and a ternary." (*Op. cit.* p. 214.) In other words, if two elements combine to form only one compound then one atom of A is combining with one atom of B. If they exhibit two compounds then one atom of A combines with one atom of B or with two atoms of B. And so on. Suppose then, for example, that we know the relative weights of oxygen and hydrogen which combine in the mass to form water to be as 7 to 1 (in Dalton's inaccurate figures). Then the relative weights of the two elementary atoms are also as 7 to 1. And so on. By similar argument he works out a table of atomic weights and what we should now call molecular weights. His view of the nature of a "compound atom" as he would call it is clearly stated: "An atom of water or steam, composed of 1 atom of oxygen and 1 of hydrogen, retained in physical contact by a strong affinity and supposed to be surrounded by a common atmosphere of heat."

DALTON'S SYMBOLS

From the beginning of his speculations, Dalton had made use of diagrammatic representations of atoms. He was careful in his published work to refer to them as "*arbitrary* marks or signs". (*Op. cit.*, p. 219.) When used to illustrate chemical facts they were shown plain. When used to illustrate the physical properties of gases they were shown with a surrounding envelope, supposed to represent heat, considered as a separate substance.

Although Dalton's original atomic theory later came under fire, the important theoretical postulate of the regularity of the combining proportions of multiple compounds was accepted when it was seen to be confirmed by independent experimental results such as those of Thomson and Wollaston. It was expressed as the Law of Multiple Proportions: when two elements A and B combine to form more than one compound, then the various weights of A which combine with a fixed weight of B bear a simple ratio to each other.

It is important to realise the sequence of these ideas. Dalton's atomic hypothesis came first: the Law of Multiple Proportions followed it.

With the publication of the *New System of Chemical Philosophy*, Dalton's greatest creative period was over, though he continued to publish and to lecture. It is plain that Dalton himself did not fully understand all .the implications of the atomic theory. Soon after the publication of Part I of the *New System*, Gay-Lussac published his discovery that when gases combine under similar conditions of temperature and pressure they do so in simple proportions by volume. In Part II of the *New System* (1810) Dalton resisted this work. He was weak in experimental skill and preferred his own inaccurate results to those of the Frenchman, so that while his colleagues were expressing satisfaction at this elegant continental support for his theory, Dalton was refusing to recognise its relevance.

There was needed to complete the chemist's atomic edifice a clear conception of a molecule. This was provided by Avogadro in 1811, but it is one of the misfortunes of science that his work was ignored for half a century. It has been suggested that Dalton had in fact conceived this principle—namely that the number of molecules contained in a given volume of any gas is constant at a given temperature and pressure. This view cannot be upheld. In some manuscript notes of a lecture he gave in Edinburgh in 1807 we find the following words: "Query: are there the same number of particles of any elastic fluid in a given volume and under a given pressure? No: azotic and oxygen gases mixed (in) equal measures give half the number of particles of nitrous gas nearly in the same volume." The course of chemistry might have been very different if Dalton had been able to take what seems a trivial step, the step of envisaging an oxygen gas molecule as distinct from an atom of elementary oxygen. Such a concept would immediately explain the example of oxygen and nitrogen giving nitric oxide without change of volume.

But it is too easy to criticise. How should we have stood in 1810 when Humphry Davy himself was not prepared, for all his brilliance, at first to accept Dalton's theory except as a guide to 'proportions'? In fact when Davy, as President, was presenting the Royal Society's first Royal Medal to Dalton in 1826, he said the award was "for the development of the chemical theory of Definite Proportions, usually called the Atomic Theory".

For half a century favour swung between rival theories of the combining weights of elements, and systems of formulation. It was not until 1860 that Avogadro's hypothesis, revived by Cannizzaro, began to play a significant part in chemical theory in the decade which saw the transformation of chemistry by the periodic classification and the doctrine of valency.

What is the significance of Dalton's work in the history of science? One feature can be expressed in the words of Davy. Dalton made "the statics of chemistry depend upon simple questions in subtraction and multiplication, enabling the student to deduce an immense number of facts from a few well-authenticated accurate experimental results. Mr. Dalton's permanent reputation will rest upon his having discovered a simple principle universally applicable to the facts of chemistry, in fixing the proportions in which bodies combine, and thus laying the foundation for future labours respecting the sublime and transcendental parts of the science of corpuscular motion." It is still the case today that virtually all chemical calculation and a large part of descriptive chemistry rest upon Dalton.

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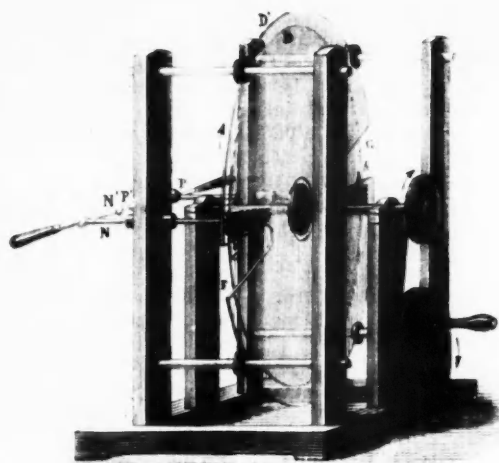
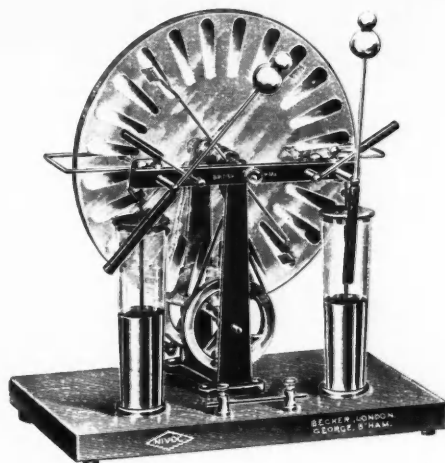FIG. 1 (*left*). An early type of influence machine, constructed by Holtz. (*Courtesy, Prof. Felici.*)
FIG. 2 (*right*). A typical Wimshurst machine as still used in elementary teaching. (*Courtesy, W. J. George & Becker Ltd.*)

ELECTROSTATIC DEVELOPMENTS

J. H. M. SYKES
Assoc.I.E.E.

Most of us can remember, from our school-days, the Wimshurst "Influence Machine", with its two glass discs and the carefully lacquered brass rods at the top, terminating in spheres between which long sparks would appear, particularly when someone turned the handle over-rapidly during a temporary absence of the science master. Electrostatics—the study of electrical energy in what was once considered to be a static form—has until recently been regarded as a subject useful only for the theoretical insight it gives into electrical principles, and for the assistance it provides in combating the nuisance caused by static electrification in industry. Examples of this 'harmful static' include the production of sparks from paper as it is handled by the printer, and the charges generated when inflammable liquids are discharged through jets, resulting in the possibility of explosion.

A survey of the present state of electrostatic knowledge may be divided into two parts. First, the design and use of electrostatic generators for high voltages; and secondly, developments in the methods used for combating harmful electrification in industry.

The need for very high D.C. voltages for nuclear fission research led those responsible for the designs of cyclotrons and similar devices to turn back the pages of the text-book, and to start afresh at designing 'influence' machines. The alternative method of providing high direct-current voltages—the use of transformers to step up the ordinary A.C. voltage, which is then rectified—proved altogether too cumbersome and costly when voltages of the order of 5 million volts, with an output current of only a thousandth of an ampere, are needed.

The principle of the Wimshurst machine, of the type we

remember from the school laboratory, is based on the elementary experiment of rubbing an ebonite rod with a silk handkerchief, and drawing sparks from it. If we could go on rubbing the rod, time and again, each time transferring the electric charge it acquires to some form of storage vessel, or condenser (now called a capacitor), we should accumulate a large amount of electricity, which would raise the capacitor to a high voltage; and with suitable arrangements we could draw off from this source for our nuclear fission experiments.

But there is a very sharply defined limit to what can be done in this way. Wimshurst, by having a large number of segments on his revolving glass plates, each of which acted as an inductor, with arrangements whereby the charge each segment accumulated was transferred to the terminal and so on to the 'Leyden jar' type of capacitor used in those early days, also found that when he began to arrive at high voltages, the machine flashed over at all sorts of unexpected places and all the charge it had accumulated was dissipated within the machine itself.

For many years, this limitation on the voltage which could be reached by the influence machine seemed insuperable; and then, in 1933, Van der Graaff and others devised a new form of electrostatic machine—though it operated on the old basic principles—which seemed to promise well. The machine used a continuously moving belt of insulating material stretched between two rollers. A charge of electricity was imparted to one end and carried to the other, where it was transferred to an electrode on which it accumulated. By providing an input from a small rectifier producing direct current, and by extending the belt for a considerable length (so that the physical separation

seems clear even if a little cumbersome between the low-voltage input end and the high-voltage output terminal was so great that flashover did not occur) the machine could produce voltages never before reached by any sort of electrical generator.

The Van der Graaff machine was further developed, both in Great Britain and America, and consequently, when the atomic physicists needed the very high voltages for their nuclear research, it was fortunately ready to supply them. By erecting the moving belt vertically, the high-voltage terminal can be put at the top (as in most electrical equipment), and supported by a large insulating cylinder inside which the belt runs, driven by an electric motor at the bottom.

The whole of the interior of the machine is nowadays filled not with air but with compressed nitrogen or sulphur hexafluoride; and this filling assists in preventing flashover and allowing the machine to be operated at very high voltages. The Van der Graaff machine at the Cavendish Laboratory works at 4 million electron volts, and produces a steady output current of 300 micro-amperes at this voltage; thus its power output is 900 watts—not quite enough to heat up a one-bar electric fire. It is about 30 feet high, and occupies a special building of its own. Other generators of this type exist at the Atomic Energy Research Establishment at Harwell, and at other laboratories engaged on similar work.

The Van der Graaff principle also has important applications in regard to X-ray equipment. The power of penetration of an X-ray tube depends on the direct-current voltage applied; and particularly for the type of equipment needed in engineering workshops for inspection of large steel components, the factor of portability is of very special importance. The use of transformers and rectifiers to provide voltages of well over 2 million volts means that the equipment is scarcely portable at all. By using a generator of the Van der Graaff type, much smaller and lighter X-ray equipment can be devised, and moreover it can operate at higher voltages than any yet contemplated with conventional equipment.

Parallel to these developments, which relate exclusively to the production of very high voltages, a research programme on different lines was instituted, in 1940, by Professor N. J. Felici, at the University of Grenoble. The purpose was to produce a range of machines which would be economic and reliable, and which would produce voltages of between 10,000 and 200,000 volts for testing purposes, work in connexion with electrostatic precipitation of smoke, etc., electrostatic paint spraying, and the provision of power for internal-combustion engine ignition systems.

The type of machine which has been developed relies, for its operation, on the fact that the electrostatic stress between two conductors in a compressed gas is many times that which can exist at atmospheric pressure. For example, theoretically a machine which will allow 100 volts to be maintained between its terminals at ordinary atmospheric pressure is capable of sustaining 20,000 volts when the pressure surrounding it is increased to 20 atmospheres.

The machines, which have been developed at Grenoble and are now commercially available, take the form of a gas-tight insulating cylinder carrying a rotor driven by a very small built-in electric motor running at a speed of about 3000 revolutions per minute. The rotor is made of a special plastic material, called Araldite, and the stator which surrounds it is of bakelite. The principle is basically the same as that of the Van der Graaff machine. A charge is sprayed on to one side of the rotating cylinder and removed at the other. Hydrogen gas is used, at a pressure of twenty atmospheres, to fill the space between the two portions, and a continuous output of 200,000 volts, at about a third of a milliampere—a power of 70 watts— can be produced. The equivalent apparatus of the ordinary transformer-rectifier type would weigh many hundredweights, and would occupy as much room as a large cabin trunk: the electrostatic equipment can be carried in one hand.

Perhaps the most interesting application of the new electrostatic generators resulting from the Grenoble researches is the production of a generator for motor-car engine ignition. This device needs no batteries or coils, and gives a more powerful spark at the plug points than the ordinary system now universally used. It is unaffected by the bad insulation conditions which frequently arise in the plugs of old engines. American manufacturing interests are now developing this system commercially.

The developments so far mentioned have been all related to the production of electrical energy by 'static' methods, for ultimate use in other equipment. We now turn to the elimination of the harmful effects of static electrification, and here a recent conference, held in London by the Institute of Physics, provided an opportunity to gain a general picture of progress in this field. Motor vehicles, on rubber tyres, become charged by the frictional effect of the separation of the tyre tread from the road surface. A remarkable fact, brought out in a paper presented to the Conference by Mr. D. Bulgin, of the Dunlop Research Centre, is that a pedal cyclist may charge himself and his machine up to a voltage of some 5000 volts to earth, as he rides along at normal speed. A bus may acquire a potential of as much as 100,000 volts. These voltages have several harmful effects. They may give shocks to passengers mounting the vehicle (although the energy stored is so small that such shocks are not likely to be dangerous to life). They may also cause 'ozone punctures' which arise from the rapid attacks made by ozone on rubber, the ozone being generated by the potential gradient across the tyre, from the point of electrification (the point of contact with the ground) to the metallic wheel.

Special type of 'anti-static' tyres have been developed to combat this phenomenon, using conducting rubber in which carbon-black is incorporated. When road tankers, for example, are discharging inflammable fluids, the establishment of the metallic hose connexion may give rise to a spark which will cause an explosion. Here, reliance on conducting tyres is not a sufficient safeguard, and the vehicles have to be bonded to earth before the hose connexions are attached, to avoid any possibility of 'static' sparking.

In the textile industry, static trouble is very prevalent. A paper by Dr. P. S. H. Henry, of the British Cotton Industry Research Association (read before the Conference) showed that static may cause a bundle of yarns to bow out

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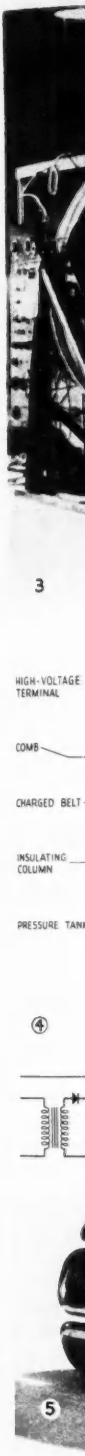
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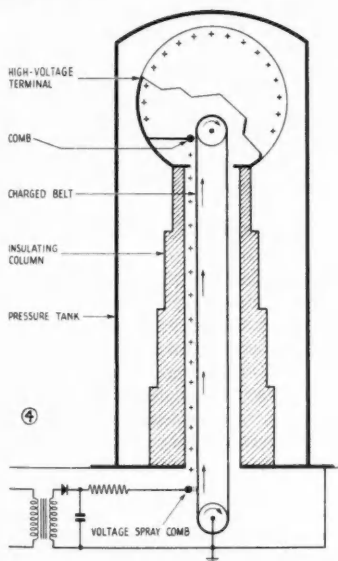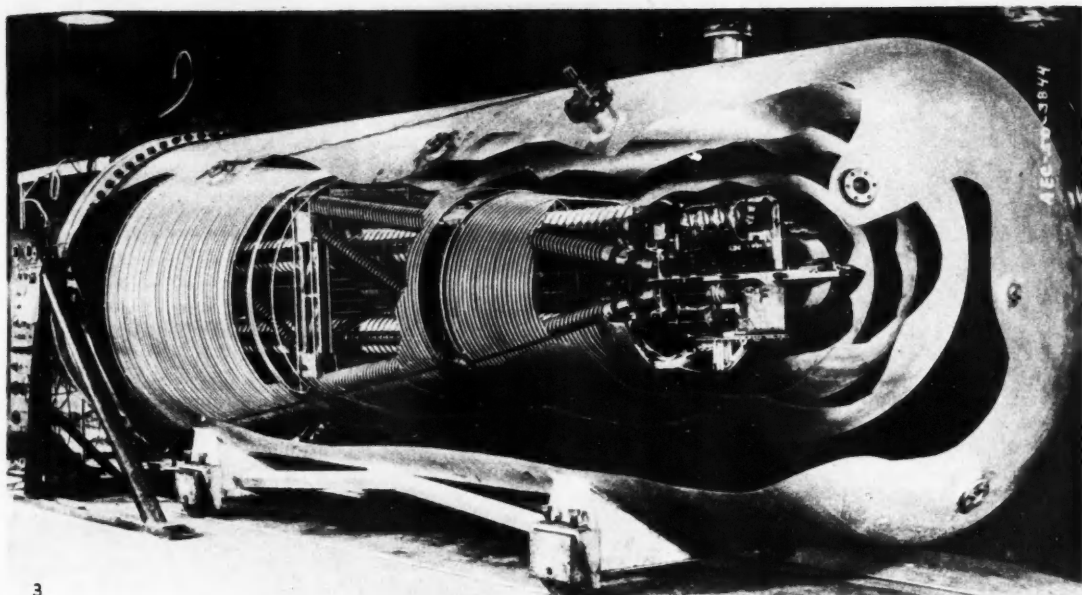INSULATING COLUMN

PRESSURE TANK

VOLTAGE SPRAY COMB

FIG. 3. Cut-away photograph showing construction of 5-million volt Van der Graaff generator of the U.S. Atomic Energy Commission's Argonne Laboratory, which can give ions that travel with nine-tenths the velocity of light. The electric charge is built up on the outermost shell which is insulated by nitrogen gas held within the outermost shell (diameter of which is 7 ft.) at a pressure of 150 lb. per square inch. The ion beam is much less energetic than that of some other types of accelerator, but is remarkably constant and is very useful for certain kinds of experiment.

FIG. 4. Diagrammatic section of Van der Graaff electrostatic generator.

FIG. 5. A modern cylinder type electrostatic generator. (*Courtesy, Prof. Felici.*)

FIG. 6. An electrostatic generator giving 200,000 volts at 1·5 milliamperes. (*Courtesy, Electricite de France.*)

FIG. 7. An electrostatic ignition unit for motor car engines. (*Courtesy, Prof. Felici.*)
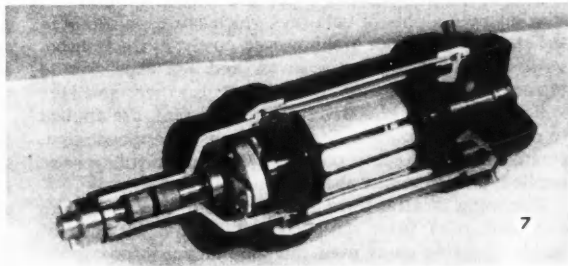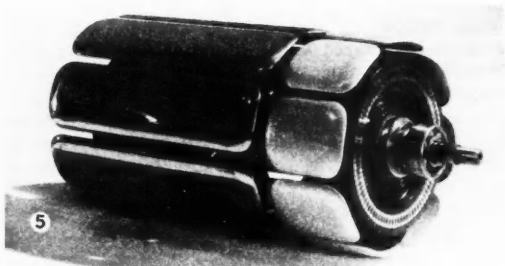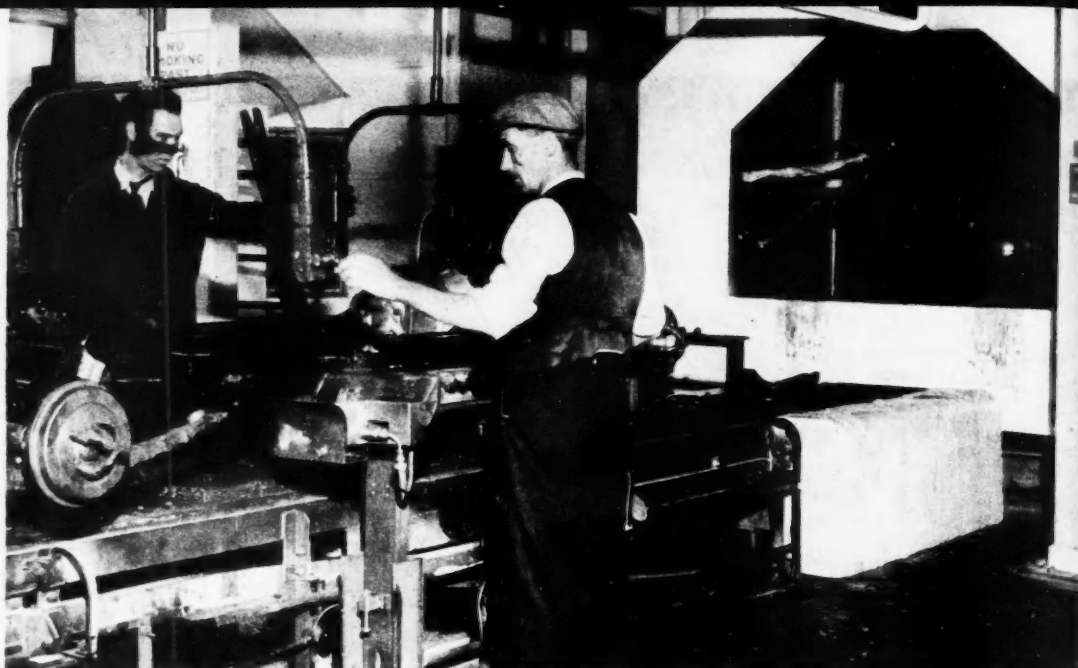
FIG. 8. Electrostatic painting of motor car chassis at the Longbridge Works of the Austin Motor Company. In the opening on the right can be seen the chassis, suspended on a travelling hook, passing inside a grid charged to 12,000 volts, the paint particles being attracted to every smallest interstice with perfect evenness.

sideways, and become unmanageable, as each thread is charged with the same 'sign'—positive or negative—and like charges repel. If textile materials are charged, they may stick to conductors, as unlike charges, induced in the conductor, attack the charges on the fibres. Dirt may also be attracted in the same way, and may cause 'fog marking'. Operatives may receive shocks, and there may be explosions due to sparks igniting inflammable dressing liquids.

To prevent the accumulations of static charges, caused through the frictional rubbing of textile materials as they are processed, various methods are used, but none can as yet claim to be completely successful under all conditions. Conducting dressings are employed, which enable the charges to be harmlessly conducted away, but these are not universally applicable. An arrangement of earthed conductors, with sharp points placed near the run of the material, is helpful. By ionising the surrounding air—thus making it conducting—static electricity can be made to leak away as soon as it is formed, and this method has been successful in recent years. Radioactive isotopes are enclosed in special containers, situated near the cloth, and they give out alpha- or beta-rays which cause ionisation in the atmosphere. They are, however, costly, as the isotopes used have limited effective lives, and are expensive to replace. A silent electric discharge is also used, and here voltages of about 12,000 volts, direct current, are applied to rows of sharp points. Streams of ions, of opposite sign, emanate from the sharp points to which these voltages are applied, and so render the air conducting.

Operating theatres form another type of location where explosion risks from static charges, in the presence of highly ignitable gases used for anaesthetic purposes, are

severe. Another paper by Mr. Bulgin showed that according to some American investigations, an insulated operating table, carrying a rubber mattress, may acquire a charge of 15,800 volts when a dry cotton sheet is stripped from it, by the frictional effect. Even a person moving on, and rising from, an artificial leather seat on an insulated metal chair may acquire a voltage of 18,400 volts. Thus sparks may easily arise.

The measures suggested for the prevention of static accumulation in operating theatres are the use of conducting rubber for all boots, sheets, anaesthetic tubing and similar objects, and also the maintenance of a high degree of humidity in the air, which assists conductivity in such fabrics as cotton, used for surgeons' and nurses' gowns. The use of radioactive thallium sources, discharging streams of ionised air into the theatre, is advocated by Mr. A. Quinton, in a paper on safety measures in operating theatres.

All the effects of static electricity are not, however, harmful. Methods have been developed, in the last two or three years, whereby paint can be sprayed on to irregular-shaped bodies by using the electrostatic attraction of the paint particles—charged positively—to the object to be painted, charged negatively—or earthed. In this way, motor car chassis are sprayed without the smallest waste of paint, and with the absolute certainty that every part of the surface will receive its due share of paint.

The text-books on electricity and magnetism which, for many years now, have devoted less and less space to electrostatics, and have plunged straight into what has seemed to be the more practical generation of power by electro-magnetic means, may have to be revised in the near future. Electrostatic science is rapidly advancing, after its fifty-year sleep.

THE BRITISH ASSOCIATION AT LIVERPOOL

This year's meeting of the British Association—the 115th—was held in Liverpool during the week September 2–9. In operation were the association's thirteen sections, of which the newest—Section X, the "Assembly of Corresponding Societies"—represents a renaissance of the old Conference of Delegates of Correspondence, and judging from its performance at Liverpool this rebirth spells a new lease of vigorous life.

According to the press hand-out the various meetings of the different sections were addressed by about 320 speakers, and their utterances accounted for a total of some 1¼ million words! But when it comes to assessing the degree of success achieved by the meeting it is, however, not so easy to find any statistical index that can be taken as a reasonably sure measure of that quality. The membership figure given was 3500, compared with 4000 at Edinburgh in 1951 and 4600 in Belfast in 1952. Belfast represented the first occasion when local schoolchildren could come to special British Association meetings—"the junior British Ass." as the press has named it—and figures just given include the junior membership, which was 815 at Liverpool as against approximately 900 at Belfast.

But mere numbers of people attending the meeting are a poor index of success. All kinds of factors interact to determine the number of people who come to British Association meetings, and many of them come into operation well in advance of the actual week of the meeting, so that the membership figure does not really reflect how interesting a particular year's programme is.

What can be said with certainty is that Liverpool and its university did everything to make the meeting successful. A fine programme of excursions had been arranged, and visitors were given every opportunity to visit the shipyards, local factories (such as those of English Electric, I.C.I., Dunlop Rubber and Distiller's Company's penicillin plant) and other places of scientific and technological interest, which includes the Tidal Institute and Liverpool's Port radar station.

Liverpool University, founded in 1903 after 21 years with university college status, was celebrating its jubilee, and the university reception on September 5 was therefore something more than a social gathering. Many of the science, medical and engineering laboratories had arranged special demonstrations. Visitors to this reception were thereby enabled to gain some impression of the range of work done in these laboratories, and to learn a little of Liverpool's notable record in science and engineering. One was able to learn some of the names of notable men associated with the university; such as Oliver Lodge and Charles Scott Sherrington. Liverpool is specially renowned in certain fields such as oceanography and marine biology; well-known names in this connexion include William Herdman, Prof. J. Proudman, W. J. Dakin and J. H. Orton. Liverpool, too, has a notable record in

chemistry. Britain's first chair of biochemistry dating back to 1902, was established at Liverpool; the first professor being Benjamin Moore, joint founder of the *Biochemical Journal*. More famous still is the man who was Liverpool's first professor of organic chemistry—Sir Robert Robinson, whose successor was Sir Ian Heilbron. The chemical factories of Merseyside are among Britain's most important and hence the existence of Liverpool's chair of industrial chemistry; the first occupant was T. P. Hilditch, who did classic researches on fats and oils, which form the raw material of such industrial enterprises as soap and margarine factories of which several are near Liverpool. The Liverpool school of physical chemistry has also done outstanding work; the first professor, F. G. Donnan, trained many now famous chemists, including Hugh Taylor of Princeton and F. A. Freeth of I.C.I. Nuclear physics is now well established at Liverpool: Chadwick, discoverer of the neutron, was there until 1948, when he was followed by Prof. H. W. B. Skinner, who took particular pride in showing visitors the synchrocyclotron, now almost finished and capable of producing protons of 400 million electron volts, at which the relativistic change of mass with energy is significant.

Liverpool too is famous for its School of Tropical Medicine, founded in 1898 and now an integral part of the university. Sir Ronald Ross was the first lecturer there. (DISCOVERY readers will remember our article about this institution by Prof. B. G. Maegraith, July 1949, pp. 224–9.)

Another scientific establishment of world importance is the Liverpool Observatory and Tidal Institute, which prepares all the British tide tables (even down to those printed in the smallest seaside towns!). This is an independent and financially self-supporting establishment, which has collaborated on many projects with the oceanographic experts of the university.

The presidential address of Sir Edward Appleton—"Science for its own sake"—was delivered towards the end of the very colourful opening ceremony in the Philharmonic Hall on September 2. By very careful planning Sir Edward brought off the double 'difficult' of starting his address at the precise moment required by the B.B.C. and at the same time eliminating the awkward gap in the proceedings which has marred the opening of several presidential addresses because the 'live' audience has been kept waiting and thereby has become conscious that it takes second rank after the radio audience. Sir Edward's was no accident but was in fact quite cunningly contrived, and future presidents need to ask him for the secret.

Sir Edward's address has been widely praised for its timeliness; what he said needed to be said at this time when the achievements of applied science, particularly those of applied nuclear physics, attract all the limelight and when all too many people believe that the main motiva-

tion of scientific research must be the aim of increasing man's mastery over natural forces and are inclined to ignore the immortal curiosity of mankind and the pursuit of new knowledge for its own sake.

All the sectional presidential addresses can be found in the *Advancement of Science* (September 1953).* Unfortunately there is not room here to mention more than one or two that were of special interest. The president of the Physiology Section, Dr. D. P. Cuthbertson, director of Scotland's Rowett Research Institute, gave a valuable review of research into the quality and quantity of protein required for the adequate nutrition of animals, including man. Biochemical research has gone so far that adequate rations of protein can now be worked out in terms of amounts of essential amino-acids. The old idea that animal proteins are first-class nutritionally and that plant proteins must be regarded as only second-class, needs to be revised in the light of modern knowledge, as N. W. Pirie pointed out recently (see DISCOVERY, "Protein Food from Leaves", July 1953, p. 199). Dr. Cuthbertson mentioned recent experiments which show that poultry can thrive and maintain egg production on diets composed solely on feeding-stuffs of plant origin, which is not unexpected if one considers the feeding habits of their wild ancestors but which does seem surprising if one thinks in terms of commercial poultry raising with its considerable reliance on things like fish meal and cod liver oil. In the case of ruminants the micro-organisms that flourish in the rumen are nutritionally important to the animal. In the cow they contribute abundantly to the supply of protein digested in the abomasum (which corresponds closely to the stomach of man and pig) and small intestine. As a result ruminants are less susceptible to deficiencies of individual amino-acids in their food proteins than are the rat, bird, pig and man. It has been possible to prove by *in vitro* experiments that the micro-organisms synthesise high-quality protein from non-protein nitrogenous compounds normally present in the rumen. Experiments have been made to show what happens if urea is fed to cattle and converted into 'microbial protein' inside the cow's gut, and the limits within which this approach yields practical results of value are now fairly well understood.

He indicated the possibilities of correcting certain native diets which are deficient in the proper amount of the essential amino-acids by means of plant proteins.

* Copies of this issue can be obtained from the British Association, Burlington House, Piccadilly, London, W.1, priced 7s. 9d., post free. Readers are likely to be interested in the book entitled *A Scientific Survey of Merseyside*, produced for this meeting, and published for the B.A. by the University Press of Liverpool; this covers the history and archaeology of the region, the local coalfields, agricultural geography, Liverpool's industrial and economic development, and the regional geology, botany and zoology. The price is 25s.

Dr. Swinton's presidential address to Section X deserves notice, in particular for his statement that the section is setting up a 'research committee' which aims to produce a series of bi-annual or triannual booklets giving the outline of educational courses in the sciences, of sources of information for adults, and a guide for young people as to ways of entering the professions.

B. A. usually provides one or two 'eye-catching' stories which are given considerable press publicity. One that hit the headlines this year was tucked away right at the end of the address by Prof. G. R. Clemo of King's College, Newcastle. His "observations on the nature of city smoke" to use his own title for them, were exploited most effectively by Chapman Pincher in the *Daily Express*, whose article attracted the attention of Lord Beaverbrook himself with the result that that newspaper is now waging a crusade against atmospheric pollution.

Among other things, Prof. Clemo referred to the possible connexion between the increasing incidence of lung cancer and soot in the atmosphere.

From atmospheric soot collected in Newcastle Prof. Clemo has isolated a dark orange compound that is chemically related to benzpyrene (which was shown in 1932, by Kennaway and Cook, to be the carcinogen responsible for tar cancer). Further work is needed before the carcinogenic status of Prof. Clemo's compound can be established, but his lecture certainly provided an additional reason why the health hazards of atmospheric pollution should be given urgent attention.

Some of the most successful sessions were those which were designed to deal with various aspects of a particular theme. Examples were those dealing with lightning discharge, new advances in underwater observation, direction-finding in animals, transmutation of elements by nuclear piles and particle accelerators; the physiology of athletic training; the industrial and engineering uses of computing machines. All these attracted big audiences, sometimes too large for the comfort of those who had to stand for two hours or more in a stuffy lecture room. Almost certainly something needs to be done to spot infiltration into such 'adult' sessions by junior members in excessive numbers.

In the lightning session, Prof. J. M. Meek described some of the work he has done in the electrical engineering department of Liverpool University. Several of the characteristic features of lightning he has been able to reproduce experimentally, in the powerful flashes he has obtained by using an impulse generator capable of giving a half-a-million-amp current flow. Mr. B. J. Mason of the Imperial College of Science and Technology put forward a new theory to explain the development of charges of the right order of magnitude inside thunder clouds.

The underwater research session include a paper by Dr. H. Barnes in which he gave more details about the method of underwater television developed at the Marine Station, Millport, and which he described in DISCOVERY recently (June 1953, pp. 172–4). Dr. H. G. Vevers of Plymouth showed photographs obtained with his underwater camera (referred to in DISCOVERY, February 1951; p. 62–3), which is yielding excellent results at depths of 35–40 fathoms—rather beyond the normal range of divers. Crabs, hermit crabs, bryozoans, starfishes, molluscs and a few fish have all appeared on the photographs at various times, but the most interesting pictures have been those of some very dense populations of the common brittle-star. This animal, which has an arm span of about 4–5 inches, is found to occur at a density of over 100 individuals per square metre in beds which may extend over an area 4–6 miles long and 2 miles wide. The brittle-stars feed on organic matter in suspension as well as on deposited detritus, and the to-and-fro action of the offshore tidal streams probably brings them a rich and fairly continuous supply of suitable food in suspension.

The films shot by frogmen armed with special submersible cine cameras is now very familiar through the work of Hans Haas, whose picture *Under the Red Sea* has been shown in many commercial cinemas. Readers will also have heard of the work of Cousteau in France (see DISCOVERY, April 1950; p. 113, in article "Films and Scientific Research" by Dr. A. R. Michaelis).

The first films of this type ever produced in Britain were made by the Royal Naval Scientific Service and were shown to the Royal Society in 1950. W. Deryck Chesterman, a physicist with the R.N.S.S., explained the technique to the British Association, and stressed the point that it is complementary to the television system and the various acoustic systems. It has an obvious use in the study of the sea-bed, and it is also being applied to other research problems (e.g. the performance of trawl nets, and the escape of young fish through the mesh).

Ultrasonic echo sounding, a development of the naval asdic technique, was described by R. E. Craig of Aberdeen's Marine Laboratory. The method can give a good record of submarine topography useful to geologists; Mr. Craig cited here the discovery of submarine canyons in the edge of the continental shelf, a problem of topical geological interest. The major use of this echo sounding, outside of navigation, is as a means of detecting fish shoals. Credit for this idea Mr. Craig gave to Skipper Ronald Balls of Yarmouth, who first called attention to its possibilities in 1935 when he demonstrated how drifter catches of herring could be increased by shooting the nets where echoes appeared.

Echoes can be obtained at a depth of around 300 metres in the deep ocean and the layer that gives this echo is called the "Deep Scattering Layer". The layer moves upwards at night (almost to the sea surface) and downwards by day, and is probably made up of crustaceans or small fish.

The special lectures designed to appeal to the junior British Ass., proved very successful. In this connexion Sir Edward Appleton set a very good example (and he certainly created a valuable precedent) by going to the trouble of preparing a special "junior presidential address" which he called "Finding things out with radio and rockets". Another highspot was the lecture demonstration by Dr. C. F. A. Pantin and Miss E. A. Robson on the subject "The simplest nervous system and how it works", the animal involved being the sea anemone. This brilliant performance was repeated at 30-minute intervals to small groups of students.

Appropriately this year's *Endeavour* essay prizes were presented by Sir Edward immediately after the junior presidential address. The first prize (50 guineas) went to J. R. Shakeshaft, for his essay on Radio-astronomy. The second and third prizes were awarded to I. H. Gould and Abdul R. Zafar respectively. In the junior section two seventeen-year-olds, G. Steward and Miss M. Green won prizes of 5 guineas, while a special prize (5 guineas) was awarded to P. C. H. Newbold for his essay "Scientific Contributions to Medicine", which was judged to be of exceptional merit for a boy of fourteen.

* * *

Next year the British Association meets in Oxford from September 1 to 8, under the presidency of Dr. E. D. Adrian, who is President of the Royal Society, and Master of Trinity College, Cambridge. In 1955 the meeting will be held in Bristol.

Guided Missiles for Britain's Three Fighting Services

On August 22, immediately before his departure for Australia where he was to visit the Woomera rocket range (scene of this month's atomic tests), the Minister of Supply issued an encouraging press statement about British developments in the guided missile field. Just over a year ago it was announced that British experts had developed guided rockets that travel at well over 2000 m.p.h., and are able to 'chase' and intercept fighter planes regardless of evasive action. The Minister's latest statement gave a little more detail about these weapons. It also referred to the development of guided rockets designed to be carried by fighters, which will increase their killing power against bombers enormously.

The statement, headed "Progress of British Guided Rockets", was as follows:

One of the matters which I shall be discussing with the Australian Government is the progress in our joint efforts on the development of guided rockets. This is in every sense a combined operation, and is an outstanding example of effective co-operation between fellow members of the British Commonwealth.

The development of these rocket weapons is carried out initially in Britain, by the experimental establishments of the Ministry of Supply, or by outside firms in

industry. [...] preliminary [...] Australia [...] explosive [...] over land [...] Woomera [...] modificat[...] most par[...] engineering [...] which ha[...] the range [...] and by [...] principal [...]

During [...] technicia[...] advances [...] rockets, [...] of the th[...] has cent[...] speed an[...]

Speed [...] In order [...] or even [...] above 5 [...] travel at [...] In achiev[...] many te[...] plexity h[...]

If it [...] destroy [...] can rele[...] must lo[...] velocity. [...] fit the ro[...] which r[...] superson[...] their pu[...] automat[...] boosts [...] smoothl[...] course o[...] engineer[...] which [...] overcom[...]

Anti-
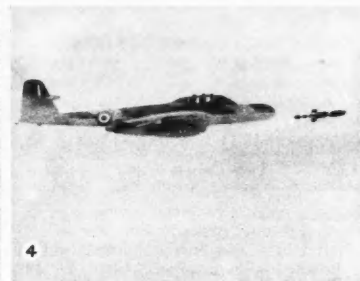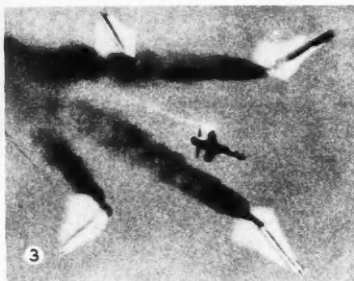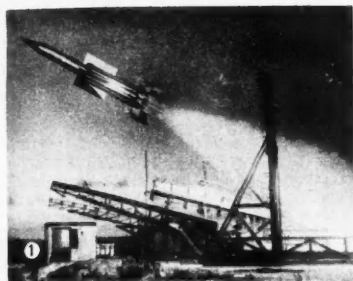
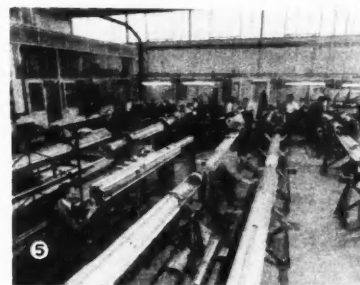*1. A guided rocket is launched at the Ministry of Supply's range at Aberporth. The attached boost motors take it to its cruising speed (about 2000 m.p.h.); the rocket then proceeds under its own power.*

2, 3. Rocket with four twin boost motors, seen falling away in photo No. 3.

4. Guided rocket is launched from a Meteor fighter.

5. Assembling guided rockets in M.O.S. establishment.

industry. After a weapon has undergone preliminary firing tests here, it is sent to Australia, where full-scale trials with explosive warheads can be carried out over land on the giant rocket range at Woomera. If in the light of these trials, modifications are needed, they can for the most part be carried out in the extensive engineering and electronic workshops, which have been set up in the vicinity of the range by the Australian Government and by the Australian branches of the principal guided rocket firms in Britain.

During the past year our scientists and technicians have made further remarkable advances in the development of guided rockets, to meet the various requirements of the three Fighting Services. Their work has centred upon two main problems—speed and guidance.

Speed is of particularly vital importance. In order to tackle bombers flying as fast as, or even faster than sound, and at heights above 50,000 ft., our rockets have to travel at more than 2000 miles an hour. In achieving this prodigious performance, many technical problems of great complexity have had to be solved.

If it is to be able to intercept and destroy an approaching raider before it can release its bombs, the guided rocket must lose no time in building up its velocity. This has made it necessary to fit the rocket with auxiliary boost motors, which rapidly accelerate it up to its full supersonic cruising speed. Having served their purpose, the auxiliary motors are automatically discarded. To make these boosts drop off simultaneously and smoothly, without interfering with the course of the missile, has presented many engineering and aerodynamic difficulties which have, however, been successfully overcome.

Anti-aircraft rockets must not only travel at high speed, but must also be able to change course rapidly if the enemy bomber takes evading action. I can say with confidence that no piloted aeroplane could hope to out-manœuvre guided rockets of the types we are now developing. They are capable of high-speed twists and turns, which create such intense strains and pressures as neither the human body nor the wings of any aircraft could withstand.

Since these stresses increase with every extra pound carried, continuous efforts are being made to reduce weight through the use of lighter materials. New methods have been evolved for moulding large plastic structures, and before very long it may be possible to make the whole of the rocket's casing out of these light materials instead of metal. This will not only reduce weight without loss of strength, but will also reduce cost—a matter of great importance.

The most complex component of a guided rocket is its steering mechanism—a kind of electronic brain. In some cases this may contain ten times as many valves as a large television set, all of which have to be fitted into a missile a few inches in diameter, and have to be made robust enough to withstand the shock of firing.

Some types of rockets are known as 'beam-riders'. They fly up a radar beam which follows the target automatically and is operated from the ground. Even at long ranges these rockets can keep themselves within a few feet of the centre of the beam.

Then there are so-called 'homing rockets'. As soon as they have been launched, these missiles take over control completely. They lock their guidance mechanism on to the enemy plane and, without any further assistance from the ground, they steer towards it, changing course as necessary. Unlike ground-controlled 'beam-riders', their accuracy is unaffected by distance. In fact, the nearer they approach the target the stronger its 'scent' becomes, and the easier it is to 'home' on to it.

In addition to missiles fired from the ground or from ships, we have reached an advanced stage in the development of guided rockets to be launched from fighter aircraft. These will increase the killing power of our fighters many times over, and will enable them to engage an enemy bomber from a distance beyond the range at which it can defend itself with any conventional aircraft gun.

Initially our efforts were concentrated on the problem of defence against enemy air attack. For this purpose a series of missiles has been evolved—some to be launched from the ground, some from ships and some from fighter planes. Whilst these anti-aircraft weapons will be the first guided rockets to be brought into service, they will be followed by other types for use in various artillery and bombardment roles.

* * * *

An article by Chapman Pincher in the *Daily Express* (August 24) named three younger scientists as the experts mainly responsible for the 2000 m.p.h. A.A. rocket mentioned by the Ministry of Supply. They are—Arnold Alexander Hall, 38-year-old director of the famed Royal Aircraft Establishment at Farnborough, Hants; Dr. Thomas Hughes, also 38, sports-enthusiast chief of the Government's rocket propulsion station at Westcott, Bucks.; and Morien Morgan, 40-year-old head of the Guided Weapons Department at Farnborough. Readers will recall that Mr. Hall this year gained the coveted distinction of being elected an F.R.S.

THE BOOKSHELF

The Living Brain by Dr. W. Grey Walter (*London, Gerald Duckworth, 1953; 216 pp., 15s.*)

Diligent readers of DISCOVERY who recollect two recent articles by Dr. Grey Walter (March 1950 and February 1952) will be prepared for some of the themes in this book. The early chapters contain an interesting account of the evolution of animal behaviour stressing the increasing control of their internal environment and the ever greater range and accuracy of information obtained about the external world by the refinement of the special senses. This is the proper biological background to an understanding of the nervous system as that part of the animal which *par excellence* enables the complexity of the environment to be 'understood' and utilised. Psychologists and neurophysiologists both make contributions to this study, and to many of them, Pavlov especially, Grey Walter pays his tribute.

The author's own contributions lie in the study of the electrical activity of the brain as a whole, which was begun seriously only twenty-five years ago by Hans Berger, a German psychiatrist. So far electro-encephalography has made its greatest advance in the clinical field, but this book attempts to sketch out how 'brain waves' may help us to understand more fundamental functions. The minute electrical activity of the cells and fibres of the brain becomes recordable from the skull only when some of the active elements are synchronised, but even then the patterns produced are exceedingly complex. At first sight one is as disheartened by them as an economist would be if he had to try to understand the workings of the Stock Exchange from the noises he could pick up through a microphone suspended from an aeroplane flying above the City of London! Grey Walter and his associates have developed electronic analysers and cathode-ray display techniques which enable them to see relationships more meaningful than those observed by standard techniques of electro-encephalography.

* * * *

The next chapters contain an account of the various machines that have been built to perform functions analogous to elementary reflex behaviour and to learning. The design of these machines is based in part on Grey Walter's electro-encephalographic studies. They are also to be seen as a contribution to the rather loose group of theories and studies known sometimes as 'cybernetics'. In this book there is a special study of conditioned reflexes of the early Pavlovian type. In many ways the most original and brilliant piece of the book is the analysis of learning in the chapter "Seven steps from Chance to Meaning" and the deduction from it of CORA (conditioned reflex analogue) the

circuit and construction of which is given in an appendix. There then follow some chapters, rather less coherent and not so well thought out, on the possible associations between brain-wave patterns and behaviour traits.

This bald sketch of the original theories of the book gives no impression of the excellence of the author's writing, the freshness of his analogies and the many thought-provoking phrases that abound throughout. These alone make it a notable non-technical scientific work—one would insult it by calling it 'popular' or 'introductory'.

A little explanation is therefore needed of the superior smiles of many scientists at much of this kind of theorising, and of cybernetics in general. With a few shining exceptions, such as Sherrington, neurophysiologists in this country have been chiefly distinguished for their contributions to our knowledge of individual nerve-cell and fibre functions and of the more peripheral motor and sensory functions of the brain. The analysis of the behaviour of the whole brain and organism has been left largely to psychologists who have constituted not a numerous body in Britain. There are several possible reasons for this, such as the distaste the empirical British have for the woolly theories often used to describe so-called "higher functions". Lord Kelvin's attitude (who was not prepared to understand anything of which he could not make a model) still appeals.

* * * *

For three centuries Descartes' mechanical animal has supplied the model for this particular problem. It is therefore small wonder that with a beast of such limited capacity little headway has been made in the analysis of brain function. This brief reference to past history will serve to emphasise the importance of the current interest in servo-mechanisms, information theory, etc., which provide fascinating analogies to certain brain functions formerly inexplicable on 'mechanical' principles. A new climate of opinion is thereby being created. The same kind of function was fulfilled by Descartes' ideas, even though they did not directly inspire much useful experimental work.

In some ways it is a pity that such an account of this work has appeared before many of the details have been thoroughly thrashed out in purely scientific works—for example, only Grey Walter has had sufficient experience of the toposcope, and only he is a master of the automatic analyser. One does not doubt the author's individual genius, a view strengthened by personal acquaintance, but even the best brains have been known to err. It would be a great pity if such an alluring book got merely the reputation of unreliability; this would be most regrettable, but it is a

possibility—for all the grey beards amongst them, the exponents of cybernetics have rather the reputation of *enfants terribles*.

D. A. POND

Mr. Tompkins Learns the Facts of Life by G. Gamow (*London: Cambridge University Press, 1953, 365 pp., 40s.*)

Professor Gamow has already written two books in which, for the benefit of the non-scientist, he has expounded most successfully some of the 'mysteries' of his own field of theoretical physics. In the present book he ventures into the world of biology and attempts to introduce some of the more fundamental aspects of the subject to the intelligent layman. Mr. Tompkins, the bank clerk son-in-law of a professor, is again the author's hero, and in lively descriptions which are full of characteristic humour we read of mysterious happenings and informative dreams.

For example, in the first dream Mr. Tompkins is transformed and injected into his own blood-stream where he takes "a long ride on an erythrocyte", followed by a "slushy walk in the intestine". A great picture is given of blood circulation, and a clear insight is given into some of the functions of different cells in terms of biochemistry and immunology.

In the chapter on heredity Mr. Tompkins' dream is somewhat more confusing—being perhaps associated with the fact that it was induced by an over-generous intake of whisky and soda! Descriptions of cell division are incoherent, and the approach to genes and gene action is a little bewildering despite the editor's footnotes which attempt to correct some of the errors. The impression gained that by looking along the chromosome one observes "a long line (of parental genes) disappearing into the dim distance" is unfortunate.

Mr. Tompkins' professional interests bring him into contact with a super electronic calculating machine, and he learns that it works by the transmission of impulses in much the same way as the human brain. After a further transformation he proceeds to explore inside his own brain, and with the aid of a guide he discovers the different centres of activity and their integration to form the nervous system of his body.

This thought-provoking book concludes with a popular lecture on the relationship between the living and the non-living. The ways in which energy is stored and dissipated are explained in non-technical terms and the essential unity of the natural sciences is clearly demonstrated.

The biologist may tend to think that Professor Gamow's book is little more than a curiosity and the layman may sometimes find it difficult to know where fantasy ends and reality begins. But no one who reads it can fail to learn much about biology, and at the same time there is provided an undoubted stimulus for further reading.

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